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Hsu et al.

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(45) **Date of Patent: Dec. 26, 2023**

(54) **ANTENNA MODULE AND ELECTRONIC DEVICE USING THE SAME**

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(73) Assignee: **Chiun Mai Communication Systems, Inc.**, New Taipei (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 367 days.

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Related U.S. Application Data

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(51) **Int. Cl.**

H01Q 5/335	(2015.01)
H01Q 21/30	(2006.01)
H01Q 1/24	(2006.01)
H01Q 23/00	(2006.01)
H01Q 9/04	(2006.01)
H01Q 13/08	(2006.01)
H01Q 5/371	(2015.01)
H01Q 3/24	(2006.01)
H01Q 25/04	(2006.01)

(52) **U.S. Cl.**

CPC ***H01Q 1/243*** (2013.01); ***H01Q 3/24*** (2013.01); ***H01Q 5/371*** (2015.01); ***H01Q 9/0407*** (2013.01); ***H01Q 13/085*** (2013.01); ***H01Q 23/00*** (2013.01); ***H01Q 25/04*** (2013.01)

(58) **Field of Classification Search**

CPC H01Q 1/243; H01Q 3/24; H01Q 5/353; H01Q 5/371; H01Q 5/378; H01Q 9/0407; H01Q 9/0421; H01Q 9/42; H01Q 13/085

See application file for complete search history.

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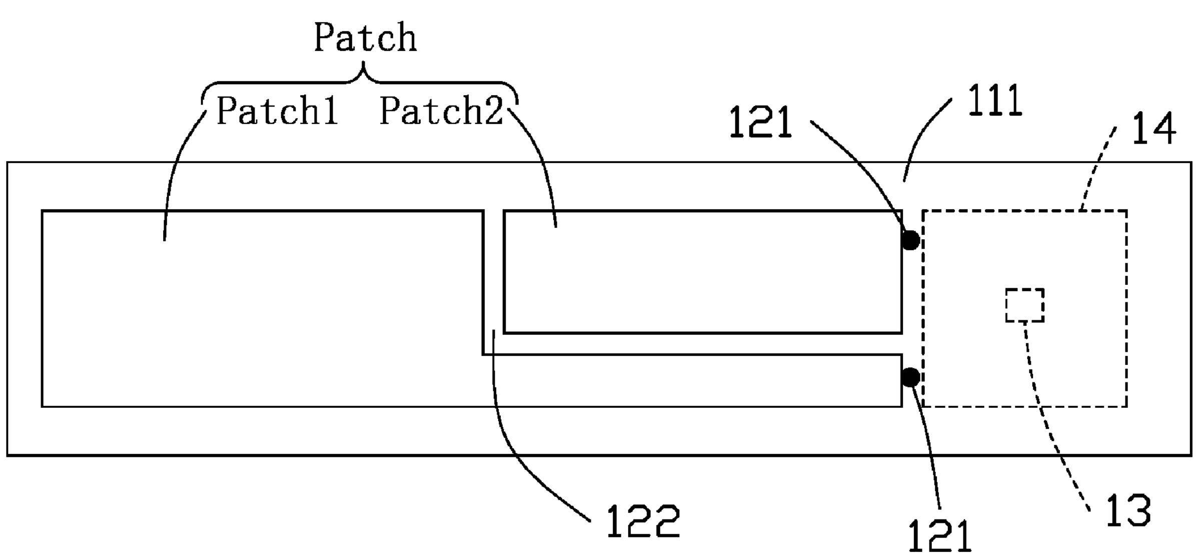
Primary Examiner — Tuan Pham
(74) *Attorney, Agent, or Firm* — ScienBiziP, P.C.

(57) **ABSTRACT**

An antenna module includes a substrate, a radiation portion, and an active circuit. The radiation portion and the active circuit are both arranged on the substrate. The radiation portion is a complete sheet body made of conductive material, at least one signal feed point is arranged on one side of the radiation portion to feed electrical signals to the radiation portion. The radiation portion defines at least one slot, the slot divides the radiation portion into radiation branches arranged at intervals. Each radiation branch is electrically connected to a signal feeding point, so as to feed electric signals to the radiation branch. The active circuit is electrically connected to the radiation portion to switch radiation modes of the radiation portion. The application also provides an electronic device with the antenna module.

16 Claims, 22 Drawing Sheets



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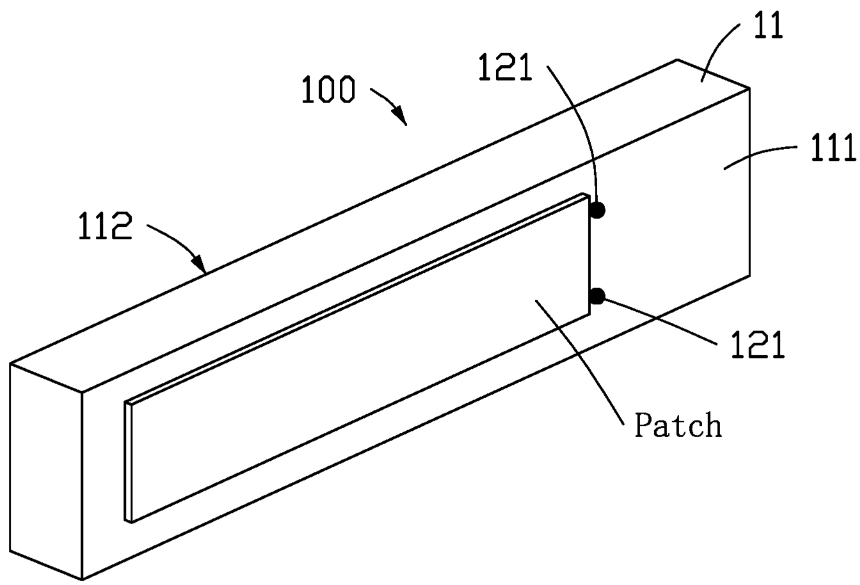


FIG. 1

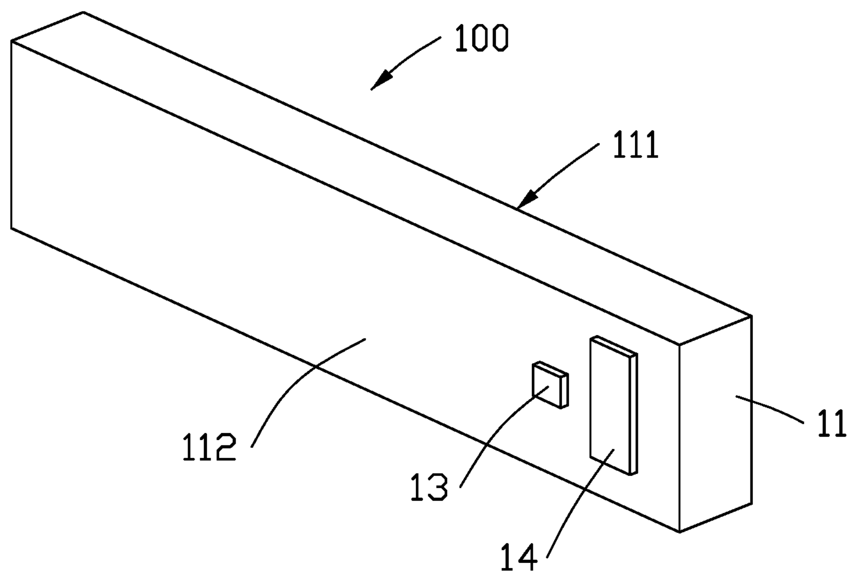
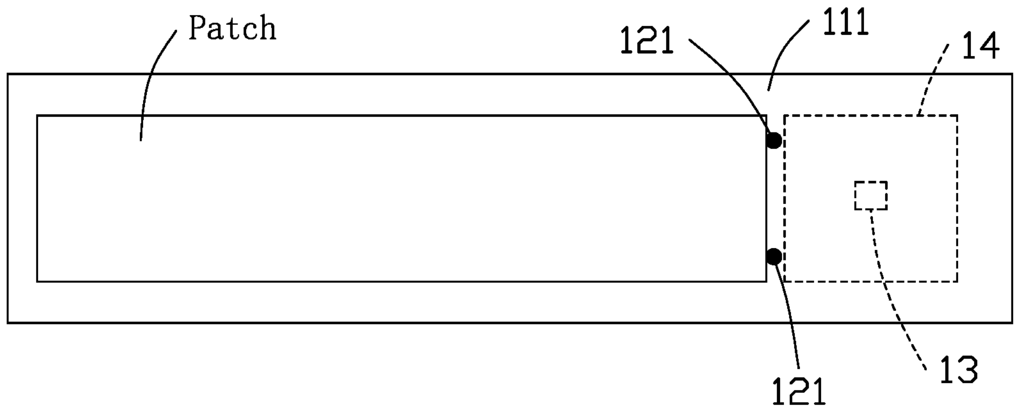


FIG. 2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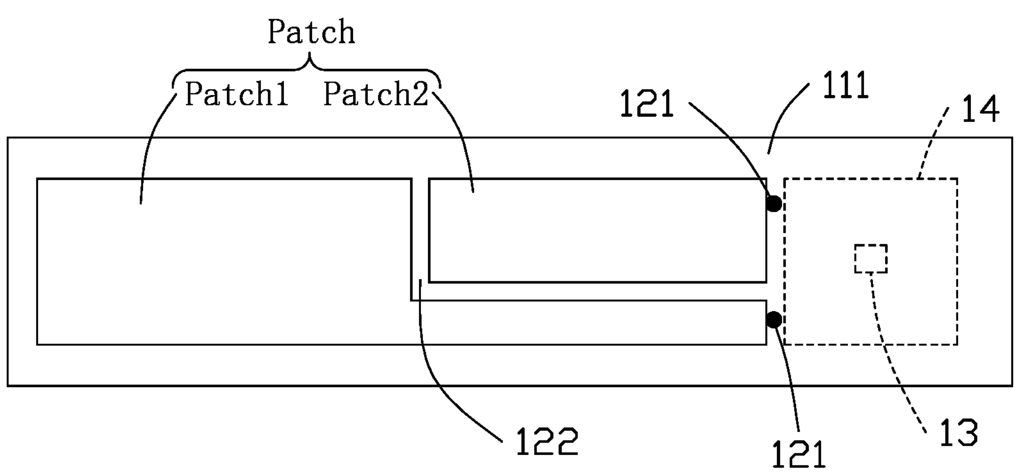
121
111
14
121
13

FIG. 3A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Patch1
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121
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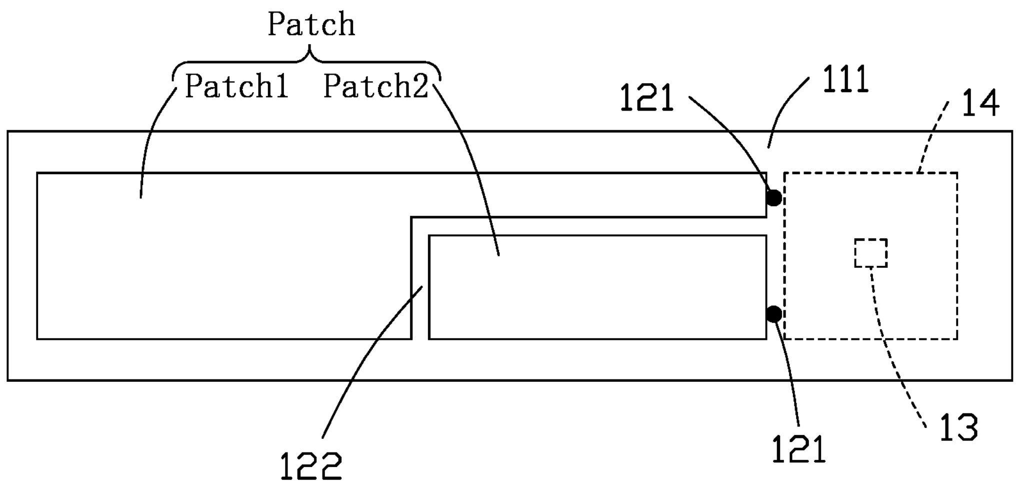
FIG. 3B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Patch1
Patch2
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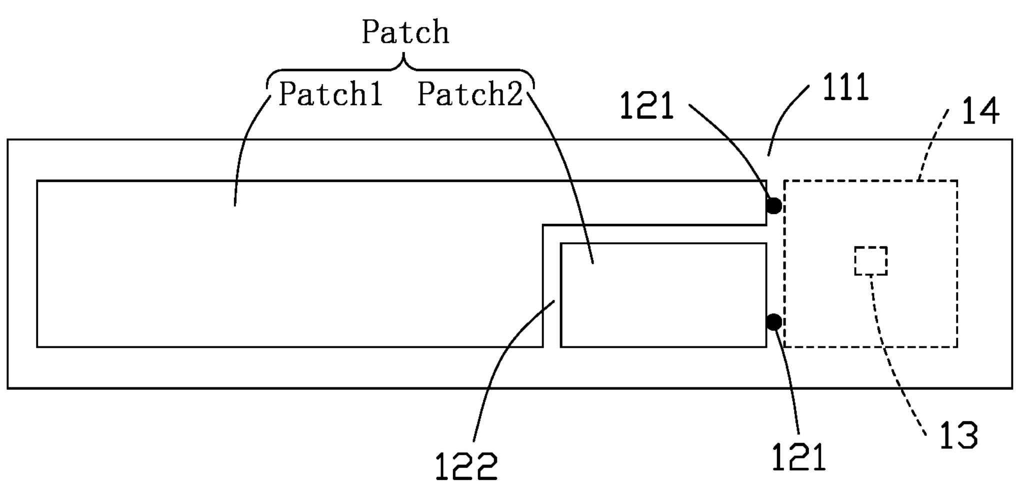
13

FIG. 3C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Patch2
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111
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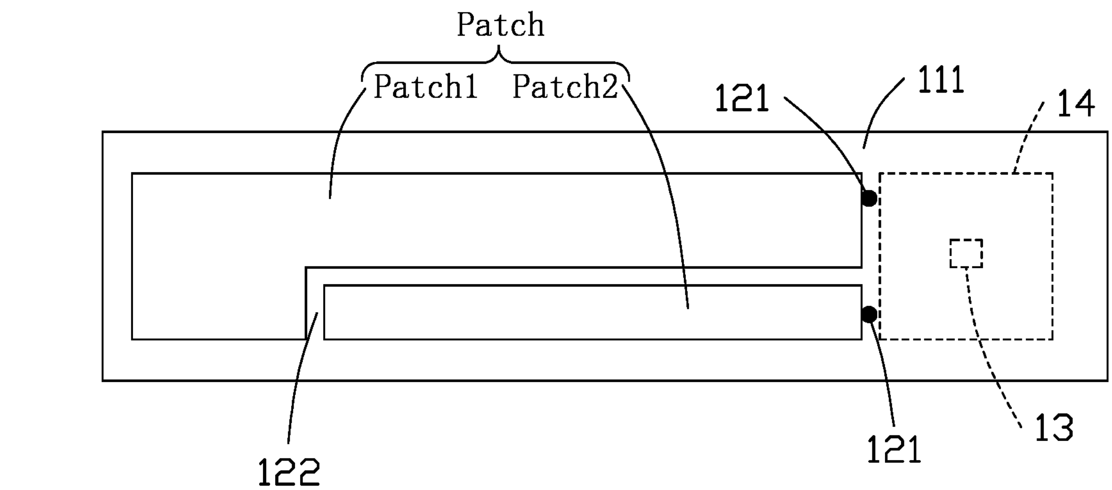
122
121
13

FIG. 3D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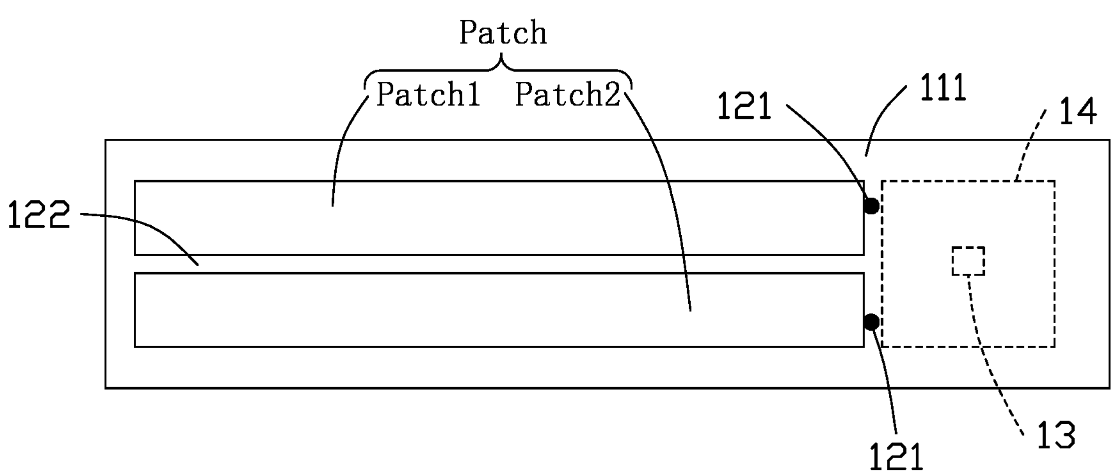
Patch1
Patch2
121
111
14
122
121
13

FIG. 3E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Patch1
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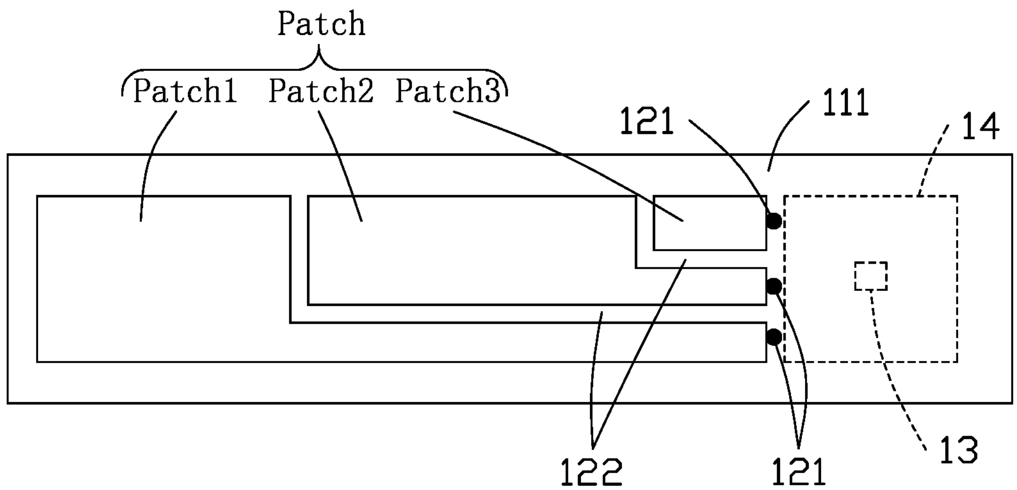
111
14
122
121
13

FIG. 3F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Patch1
Patch2
Patch3
121
111
14
122
121
13

FIG. 3G

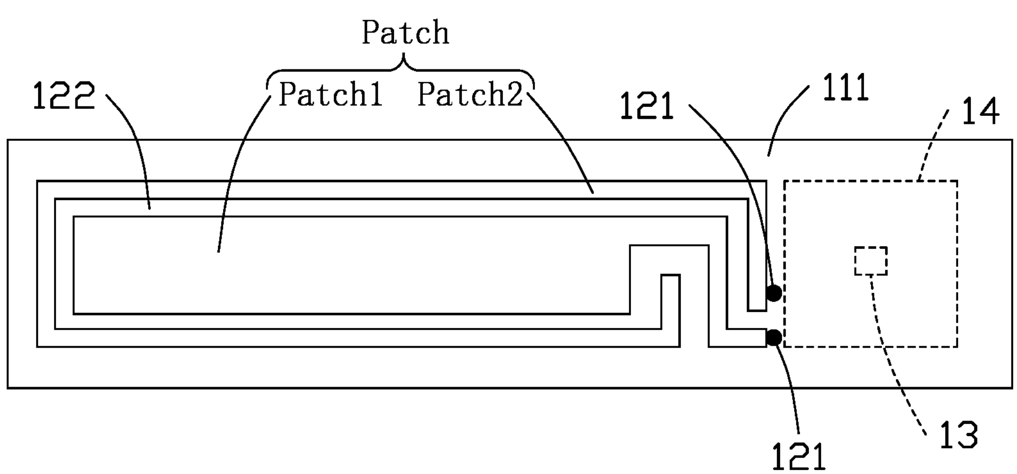
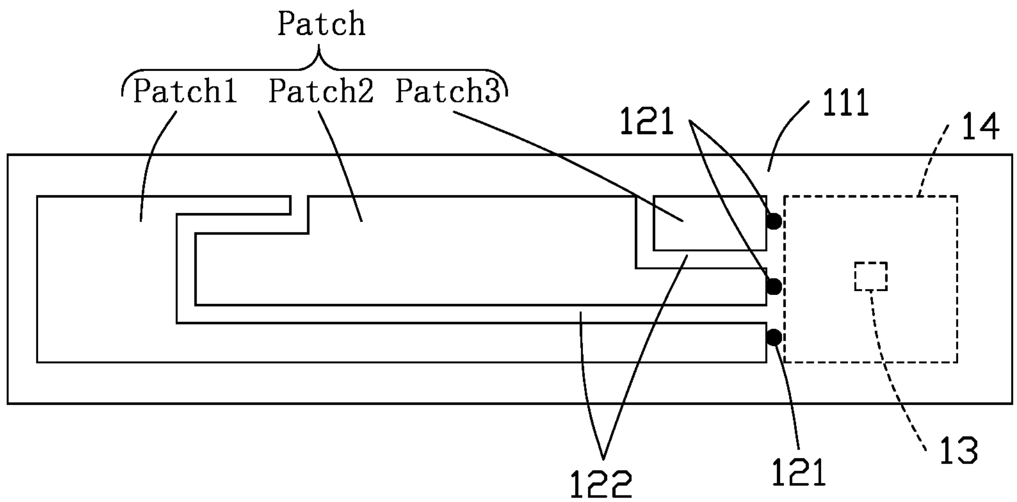

Patch
122
Patch1
Patch2
121
111
14
121
13

FIG. 3H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Patch1
Patch2
Patch3
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111
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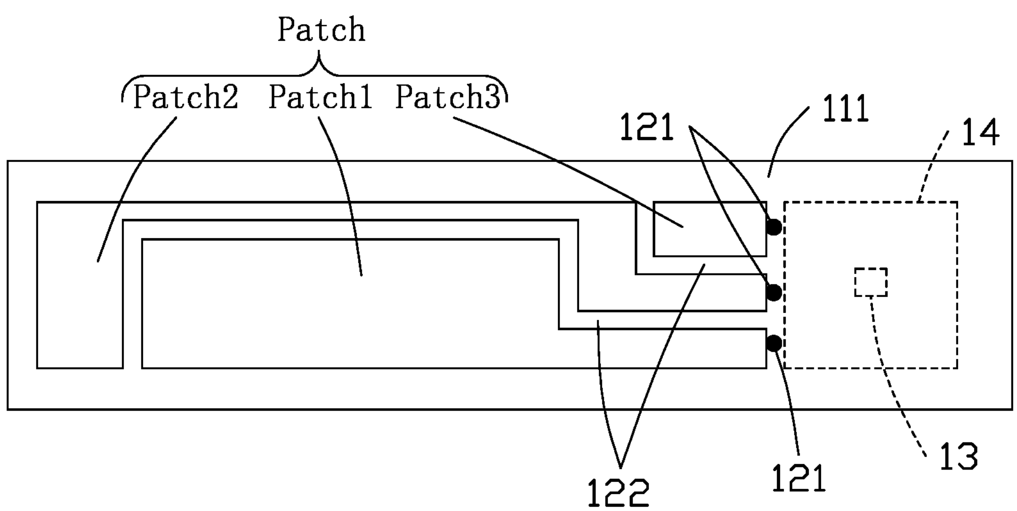
122
121
13

FIG. 3I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Patch2
Patch1
Patch3
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111
14
122
121
13

FIG. 3J

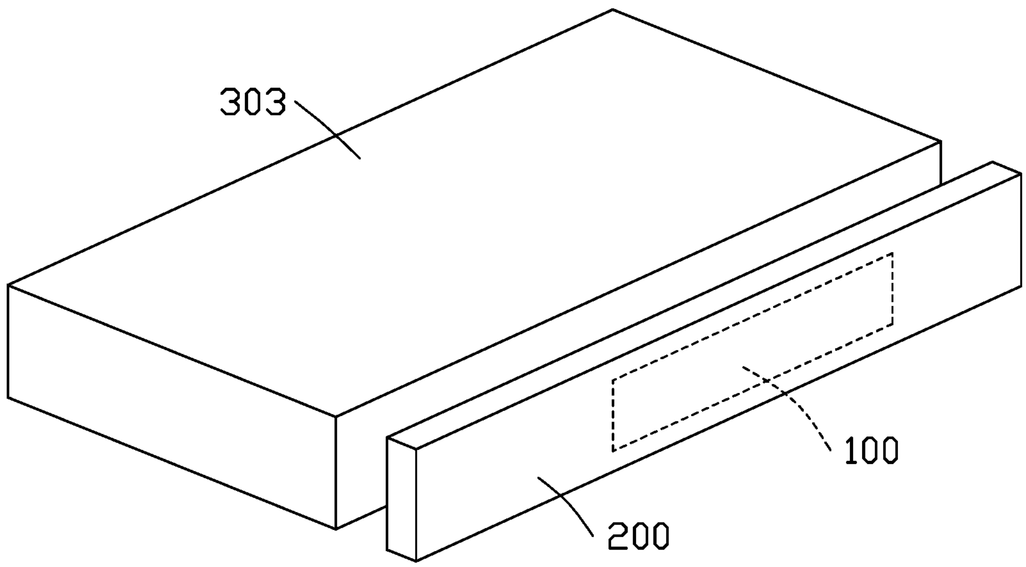


FIG. 4

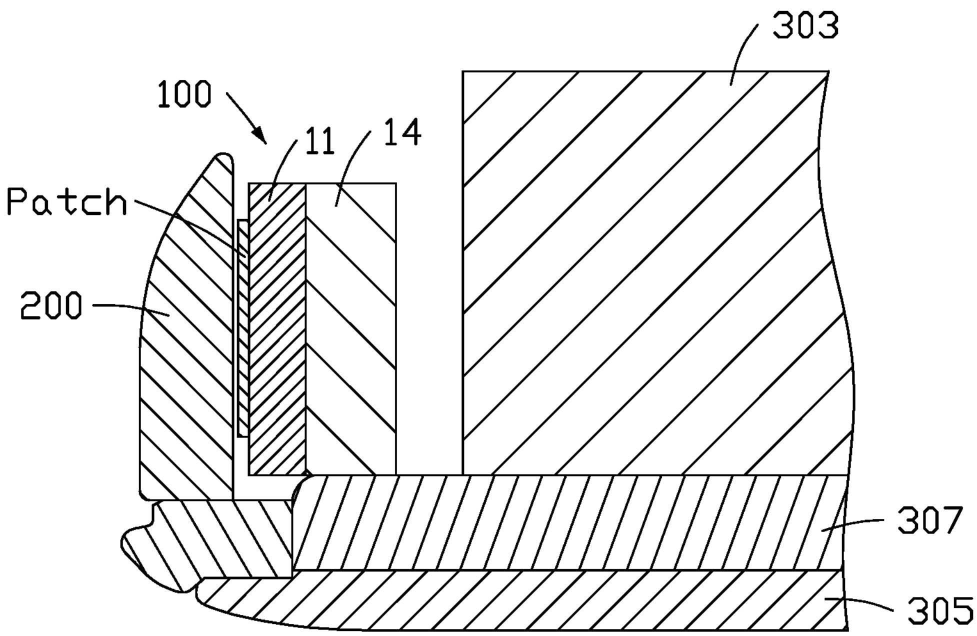
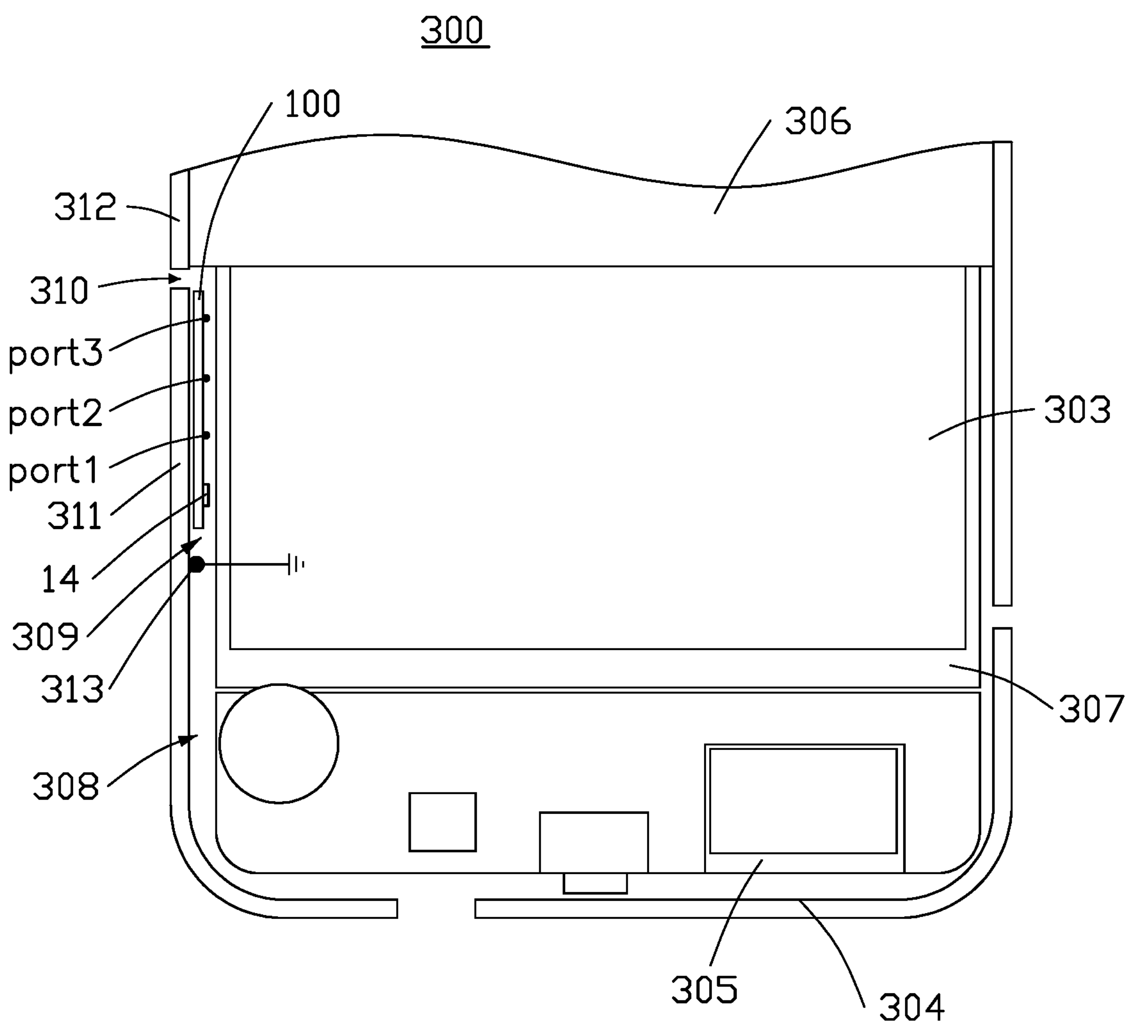


FIG. 5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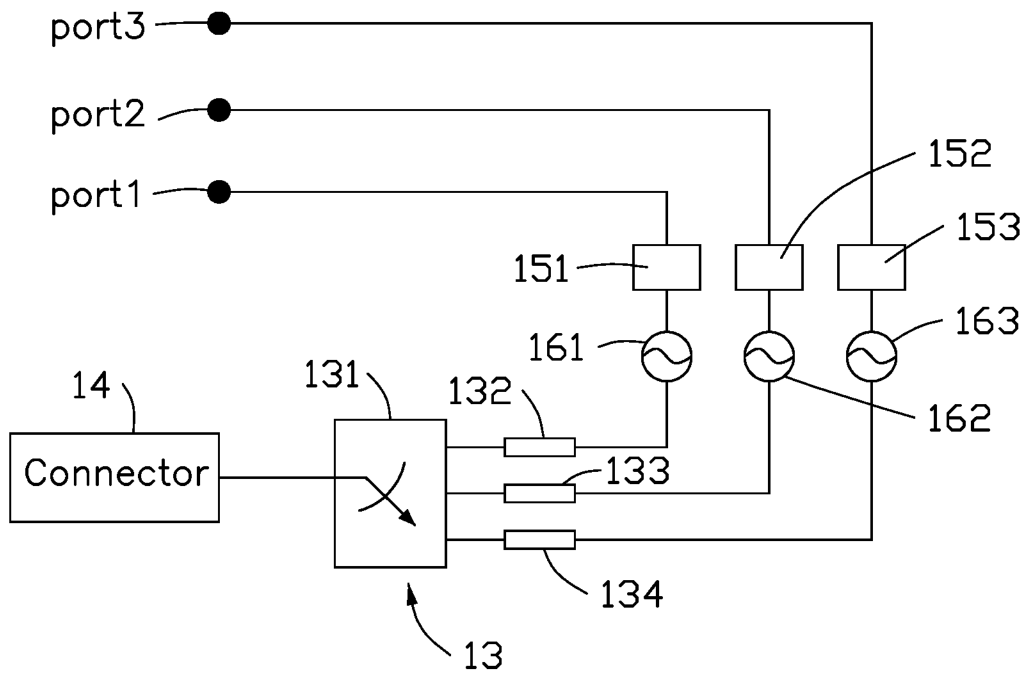
312
310
port3
port2
port1
311
14
309
313
308
303
307
305
304

FIG. 6


port3
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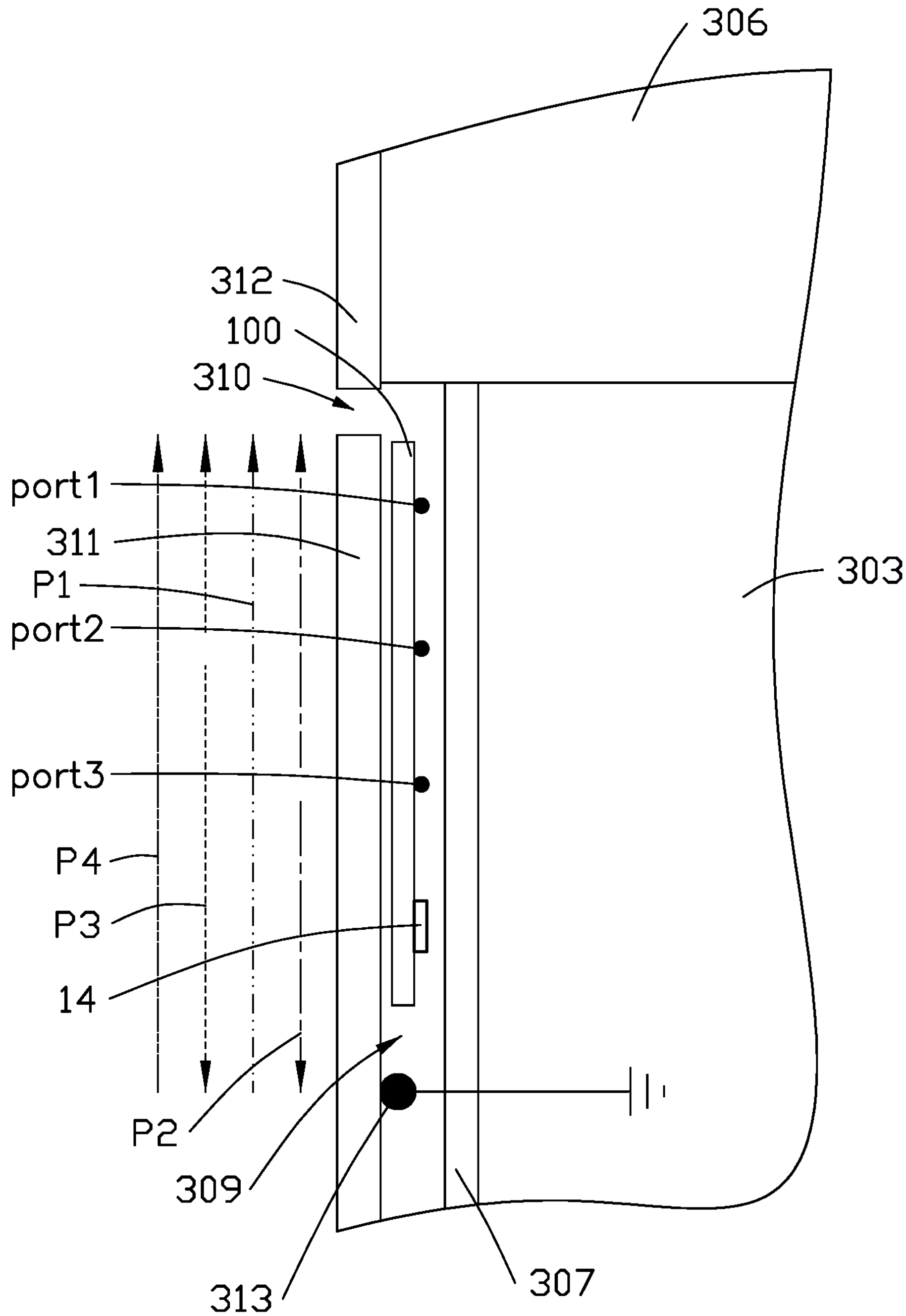
port1
152
153
151
161
163
14
131
132
162
Connector
133
134
13

FIG. 7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312
100
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port1
311
P1
port2
port3
P4
P3
14
P2
309
313
307
303

FIG. 8

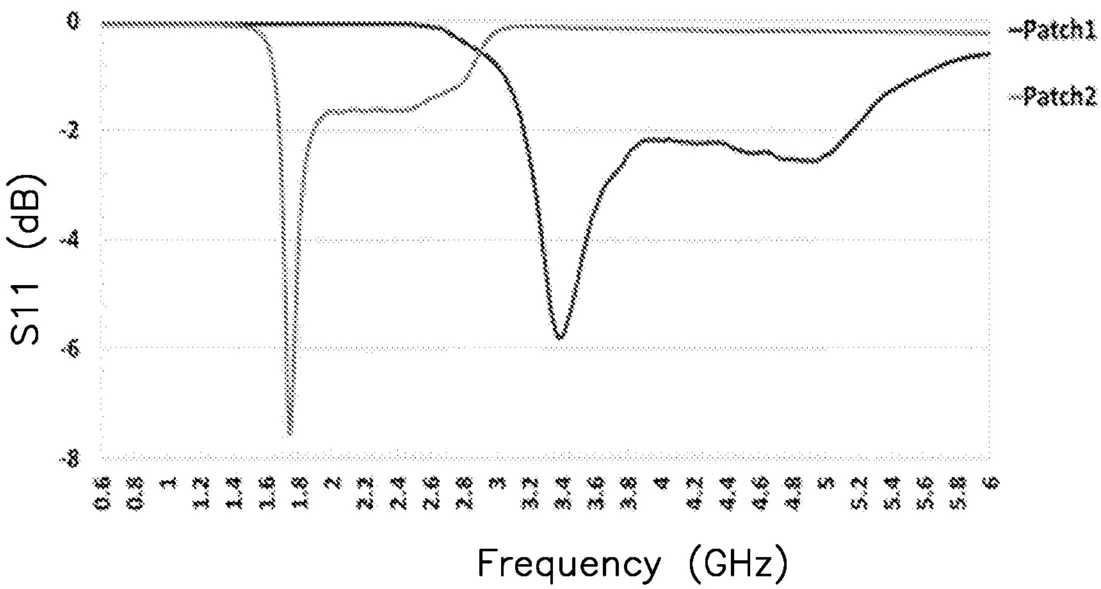
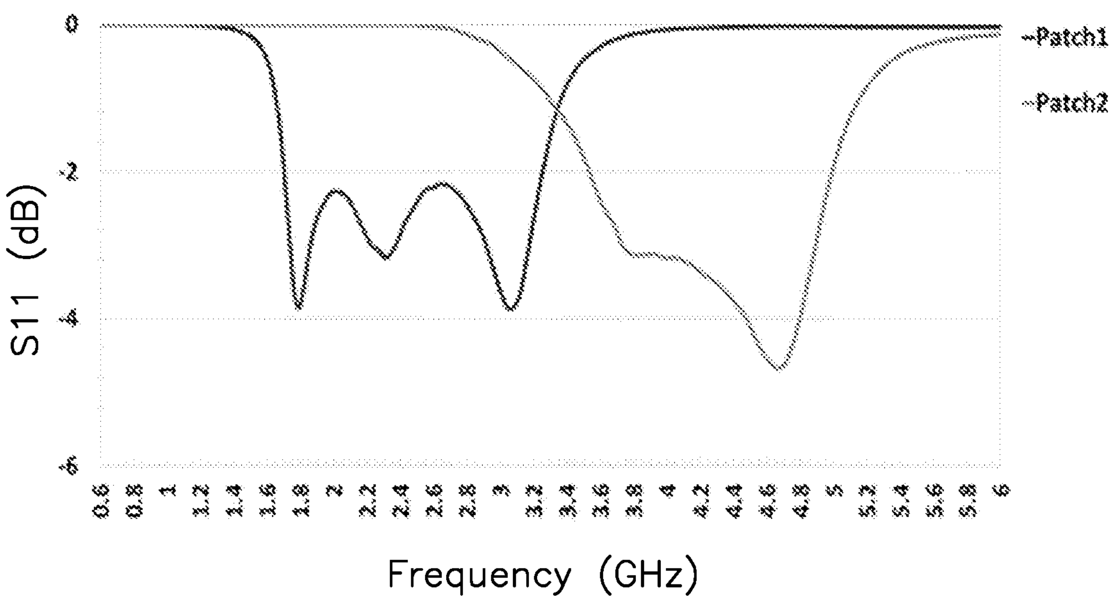

0
-2
-4
-6
-8
S11 (dB)
0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8 5 5.2 5.4 5.6 5.8 6
Frequency (GHz)
Patch1
Patch2

FIG. 9A


0
-2
-4
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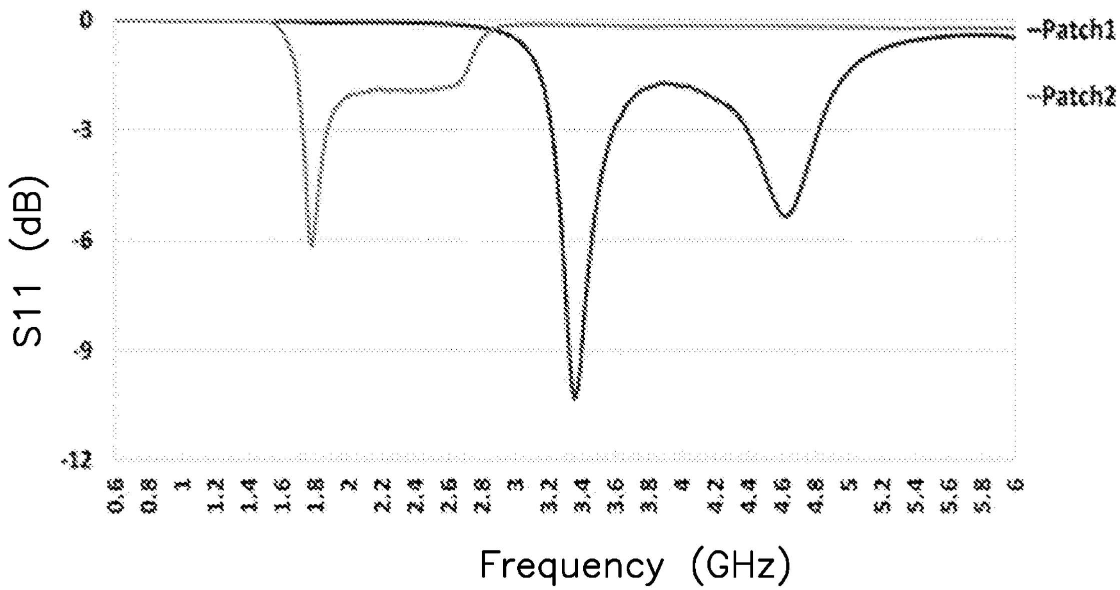
S11 (dB)
0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8 5 5.2 5.4 5.6 5.8 6
Frequency (GHz)
Patch1
Patch2

FIG. 9B


0
-3
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-12
S11 (dB)
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8
4
4.2
4.4
4.6
4.8
5
5.2
5.4
5.6
5.8
6
Frequency (GHz)
Patch1
Patch2

FIG. 9C

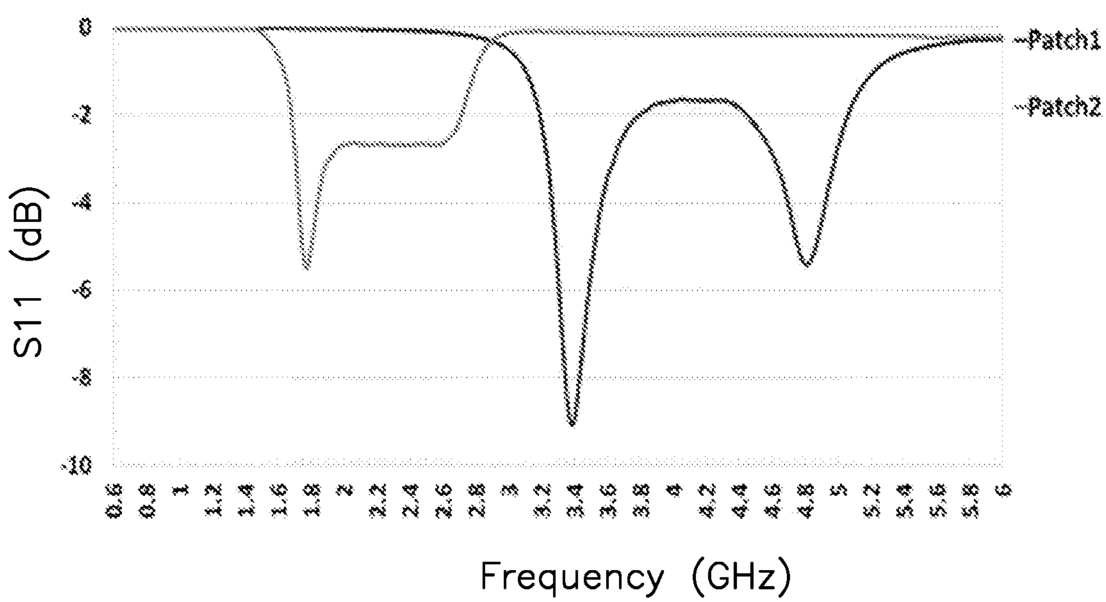

0
-2
-4
-6
-8
-10
S11 (dB)
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8
4
4.2
4.4
4.6
4.8
5
5.2
5.4
5.6
5.8
6
Frequency (GHz)
Patch1
Patch2

FIG. 9D

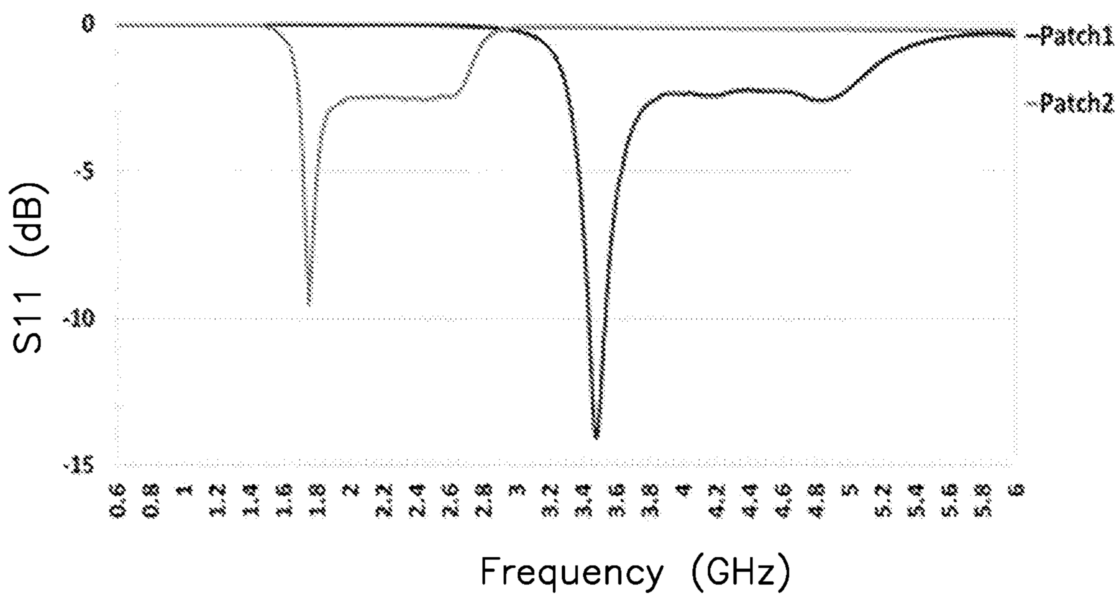

0
-5
-10
-15
S11 (dB)
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8
4
4.2
4.4
4.6
4.8
5
5.2
5.4
5.6
5.8
6
Frequency (GHz)
Patch1
Patch2

FIG. 9E

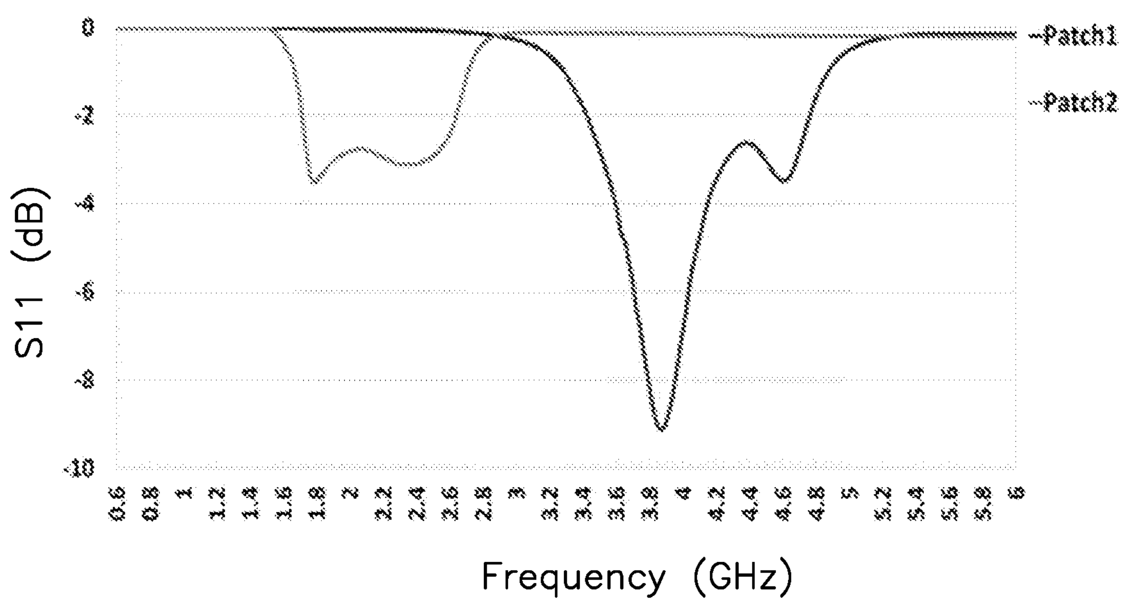
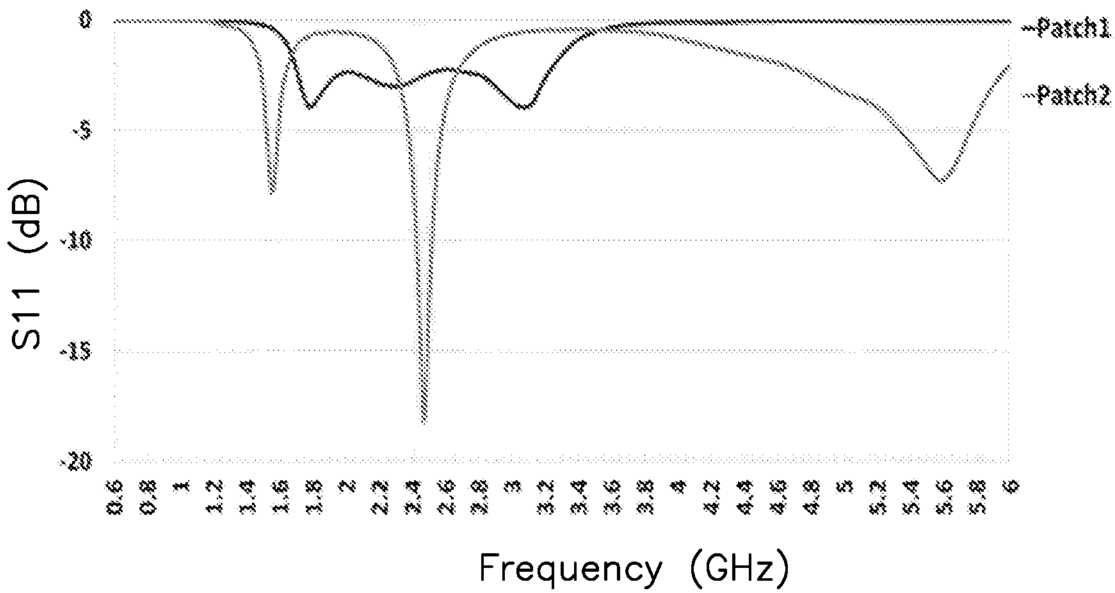
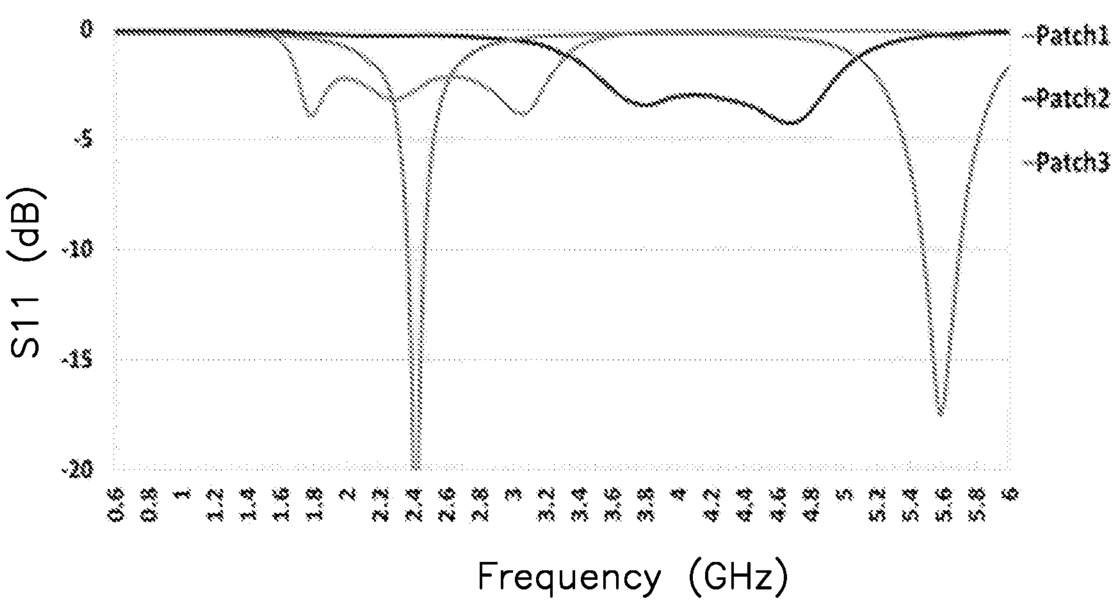

0
-2
-4
-6
-8
-10
S11 (dB)
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8
4
4.2
4.4
4.6
4.8
5
5.2
5.4
5.6
5.8
6
Frequency (GHz)
Patch1
Patch2

FIG. 9F



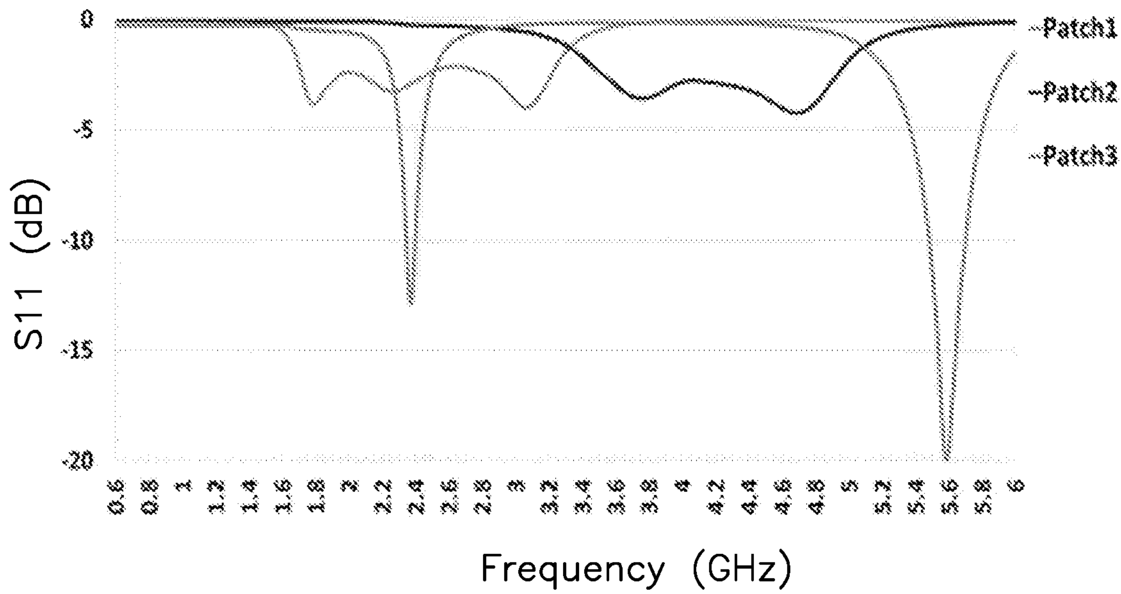
0
-5
-10
-15
-20
S11 (dB)
0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8 5 5.2 5.4 5.6 5.8 6
Frequency (GHz)
Patch1
Patch2

FIG. 9G



0
-5
-10
-15
-20
S11 (dB)
0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4 2.6 2.8 3 3.2 3.4 3.6 3.8 4 4.2 4.4 4.6 4.8 5 5.2 5.4 5.6 5.8 6
Frequency (GHz)
Patch1
Patch2
Patch3

FIG. 9H


0
-5
-10
-15
-20
S11 (dB)
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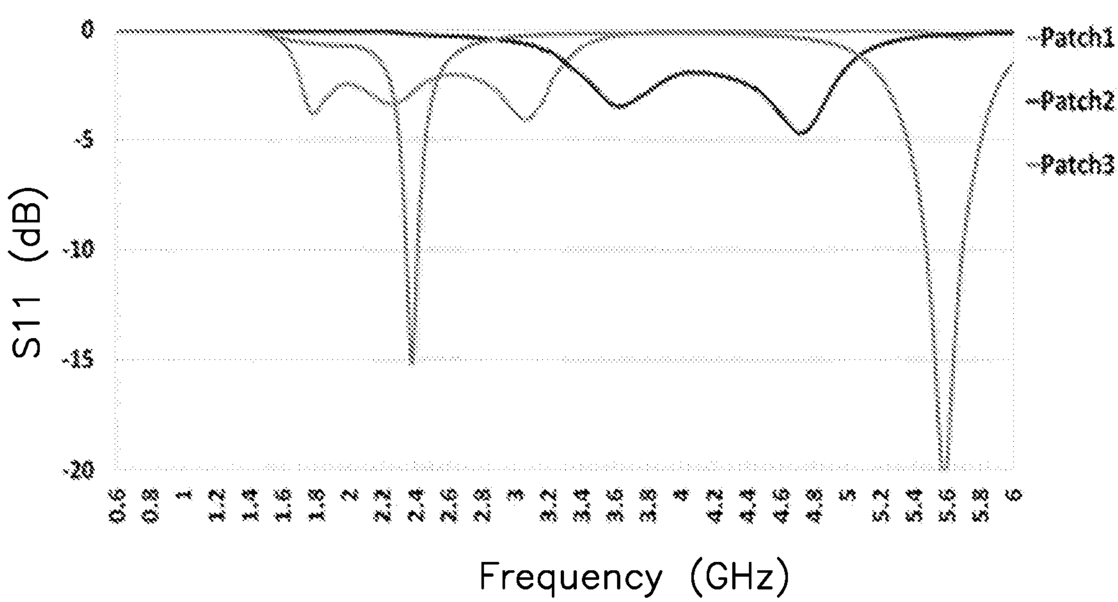
Frequency (GHz)
Patch1
Patch2
Patch3

FIG. 9I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-5
-10
-15
-20
S11 (dB)
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Frequency (GHz)
Patch1
Patch2
Patch3

FIG. 9J

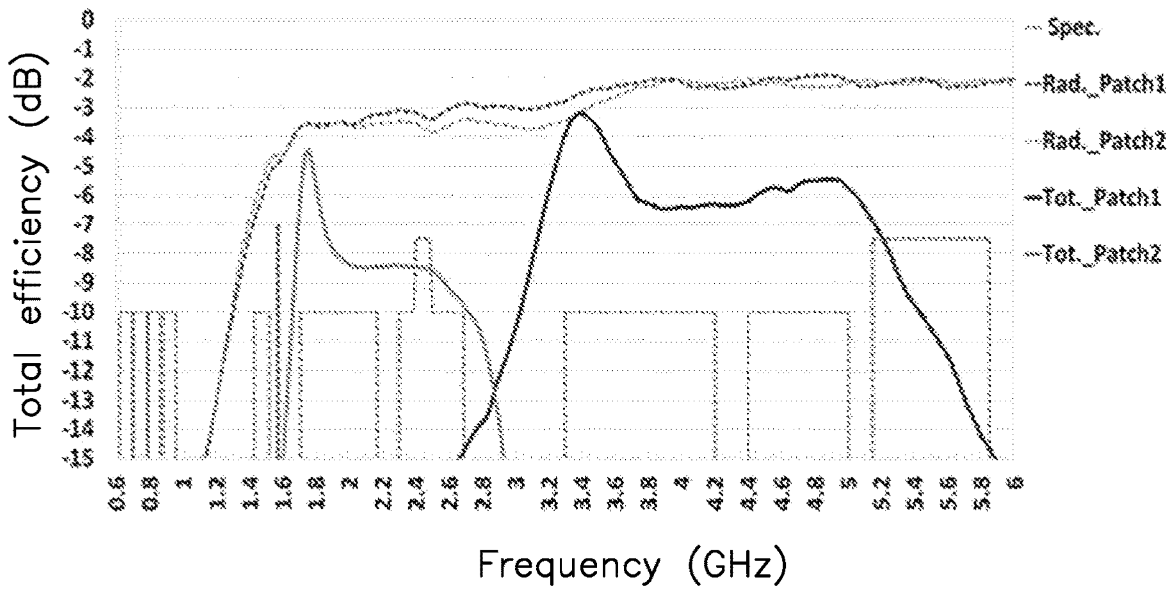

FIG. 10A

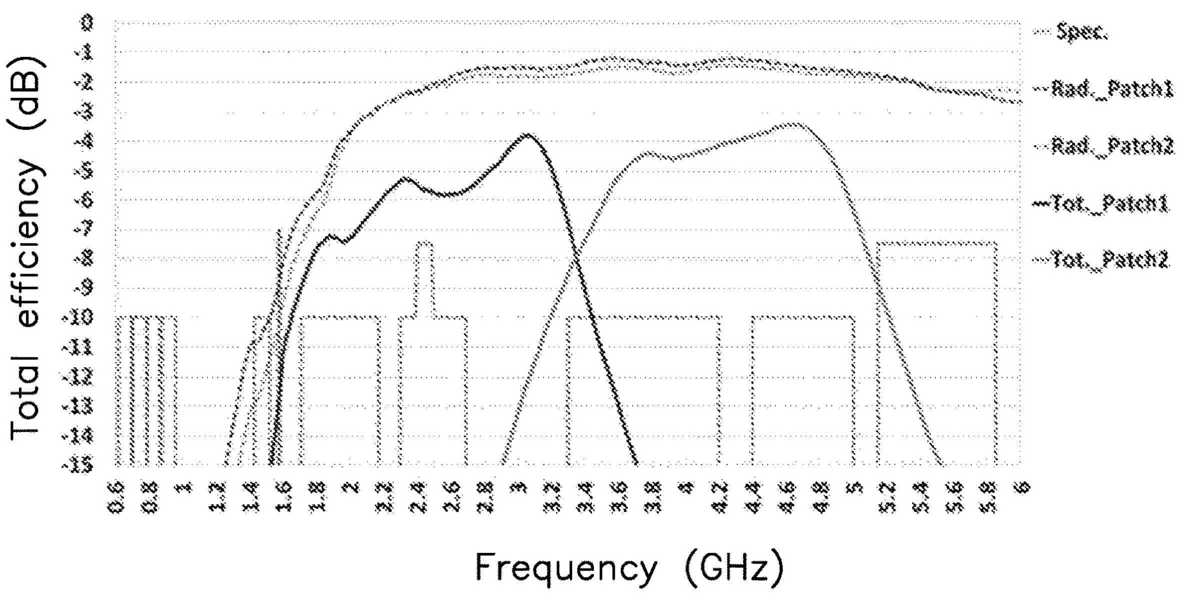

FIG. 10B

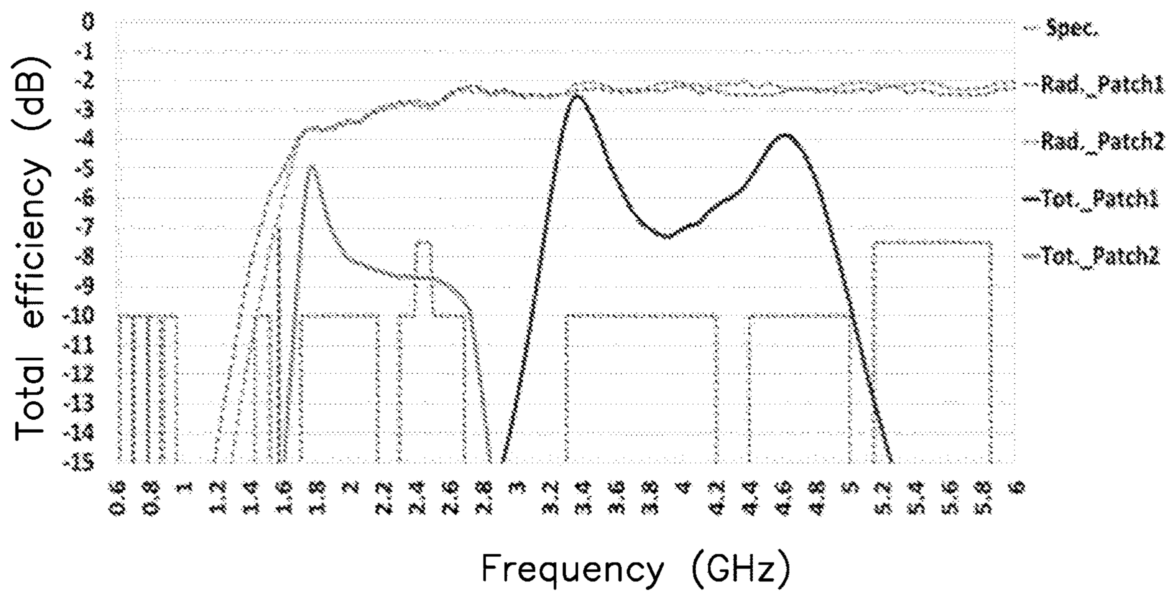

FIG. 10C

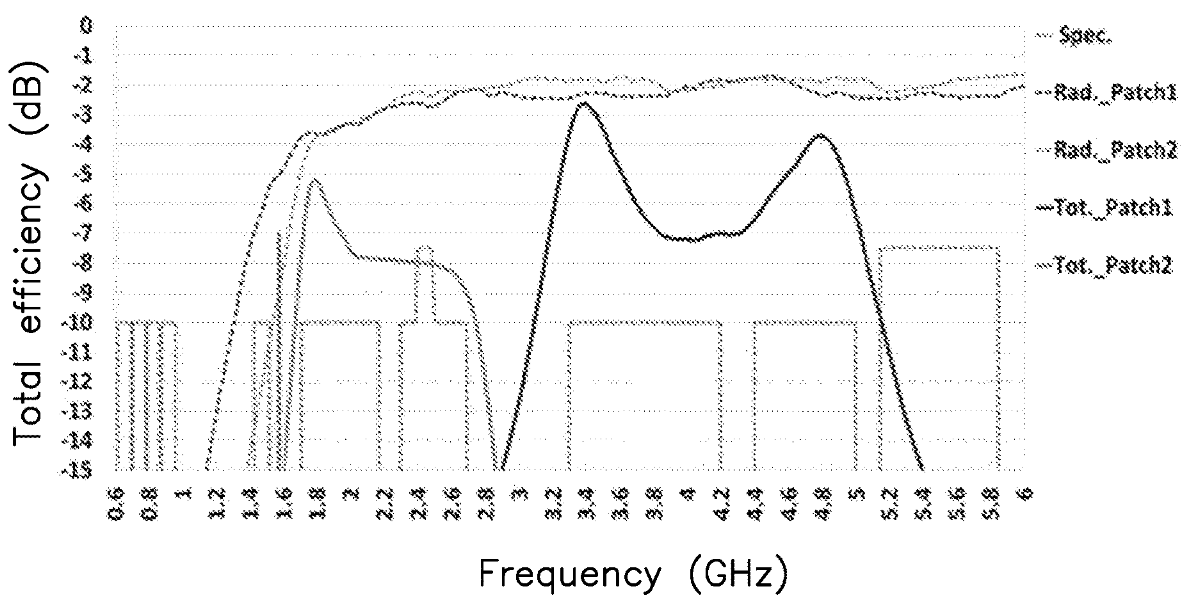

FIG. 10D

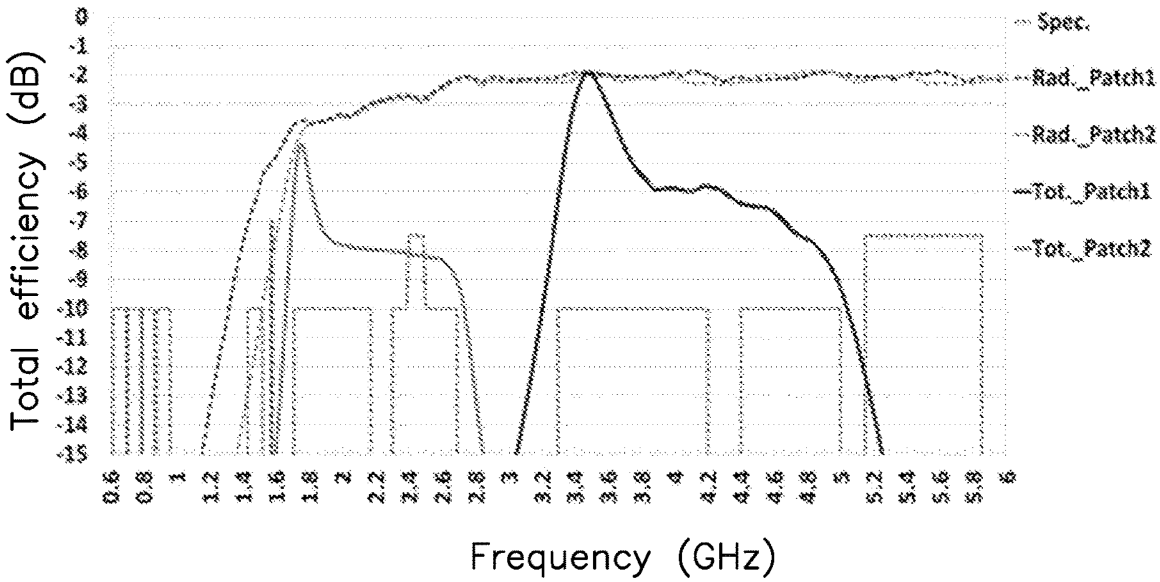

FIG. 10E

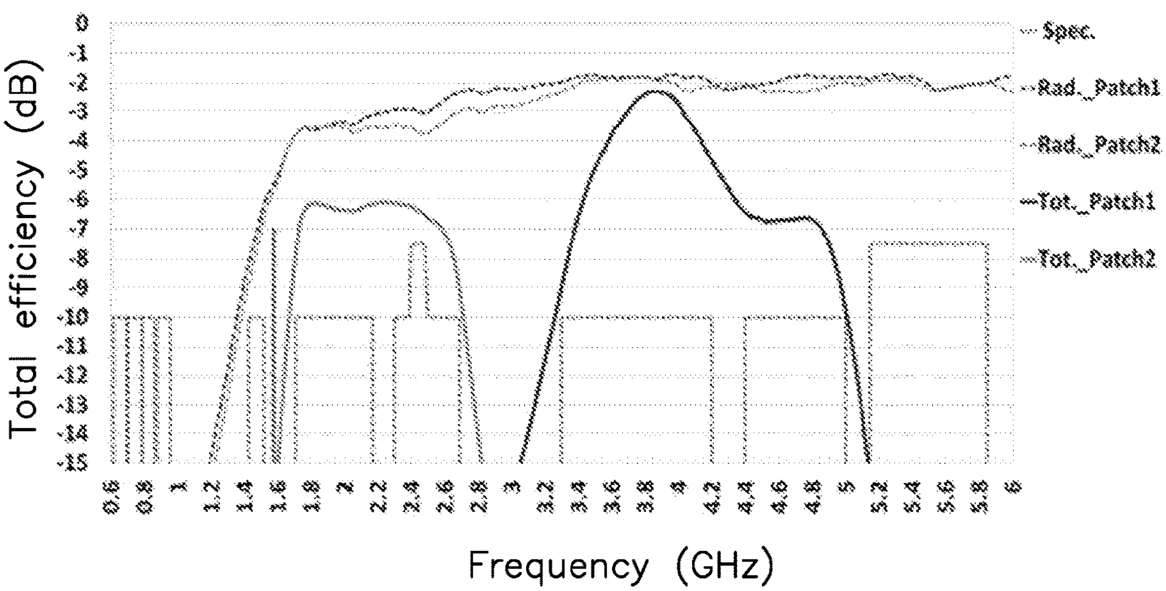

FIG. 10F

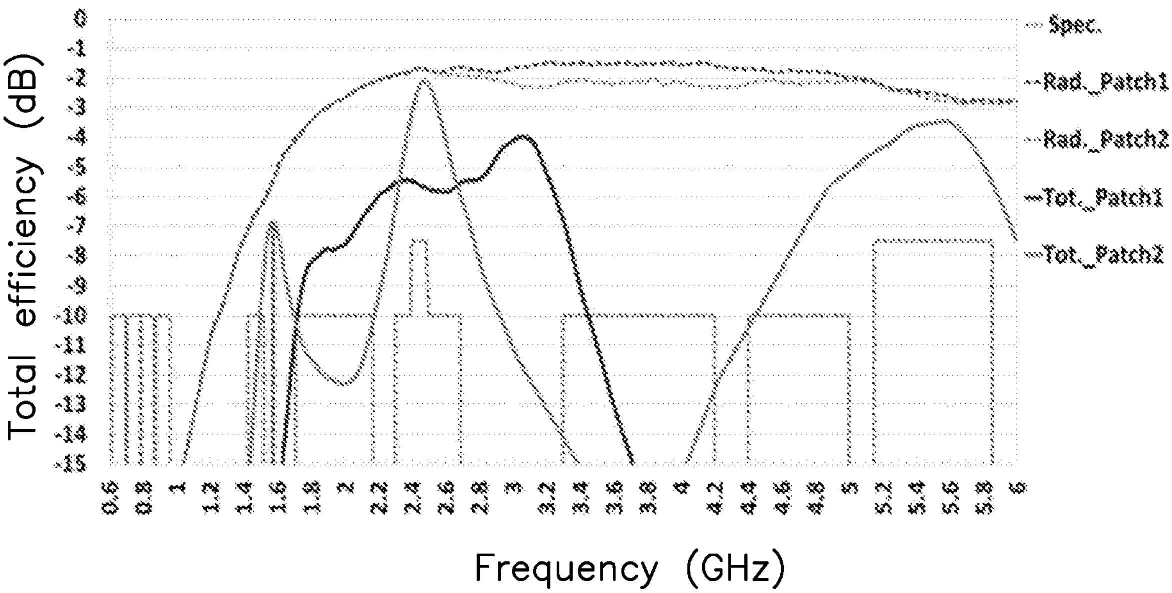

FIG. 10G

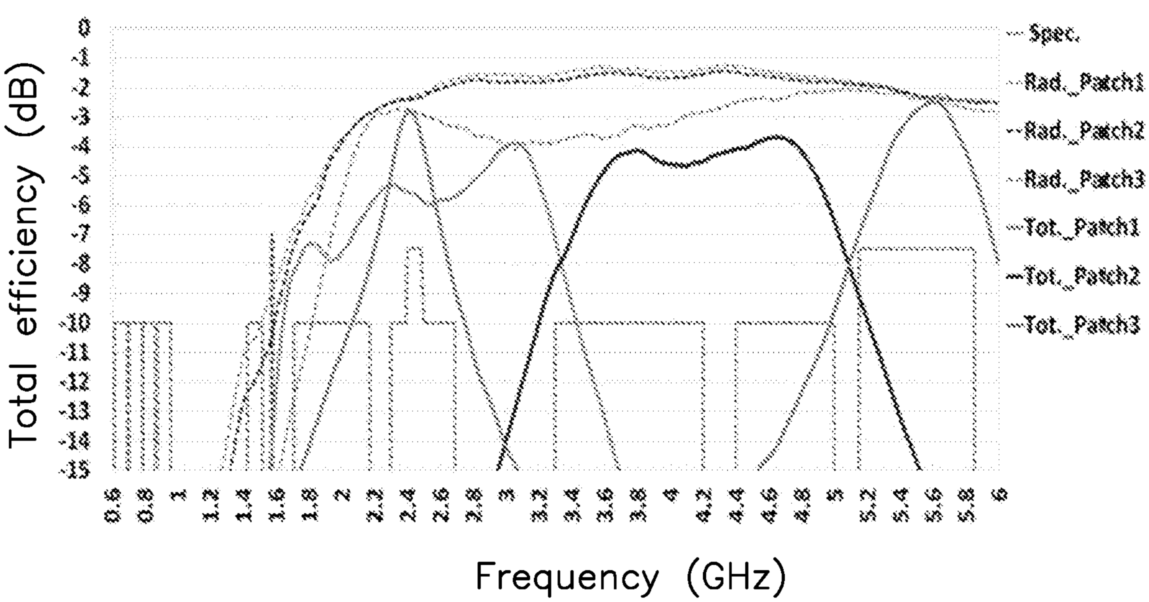

FIG. 10H

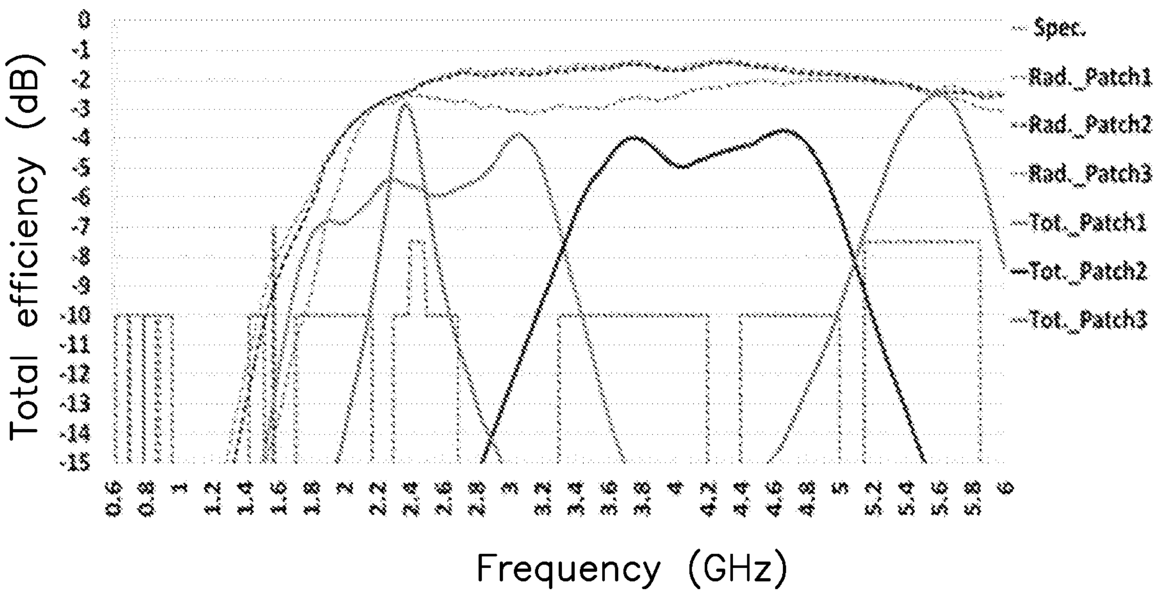

FIG. 10I

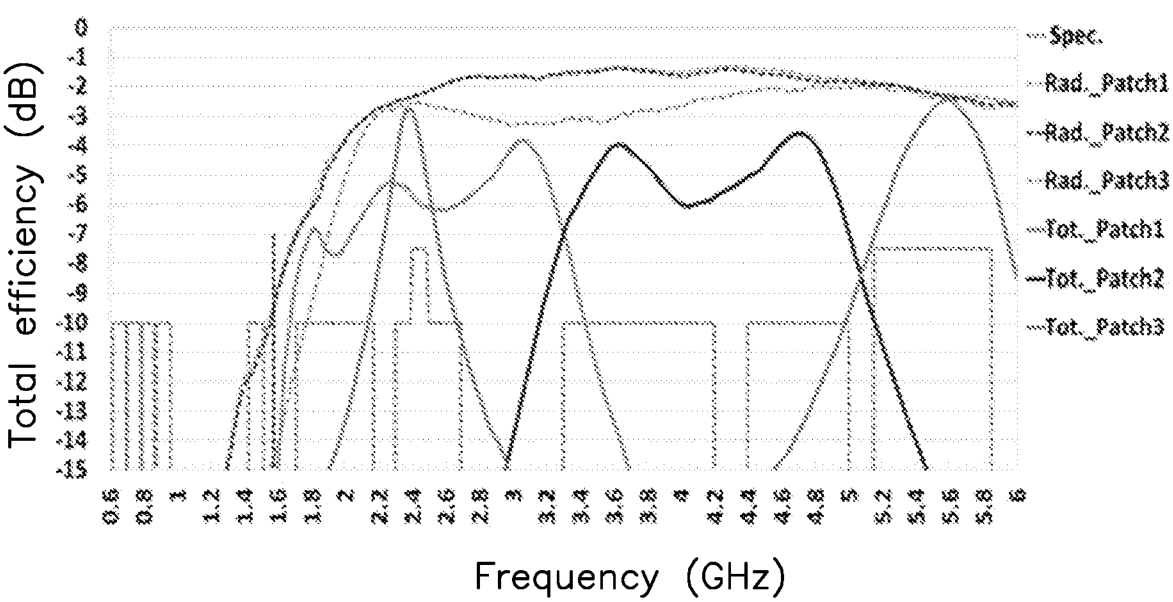

FIG. 10J

ANTENNA MODULE AND ELECTRONIC DEVICE USING THE SAME

TECHNICAL FIELD

The present disclosure relates to the field of communication technology, in particular to antenna module and electronic device.

BACKGROUND

With the advancement of wireless communication technology, electronic devices such as mobile phones continue to develop toward the trend of diversified functions, thinner and lighter, and faster and more efficient data transmission. The space that can receive antennas is getting smaller and smaller, and with the continuous development of wireless communication technology, the demand for antenna bandwidth continues to increase. How to design an antenna with a wider bandwidth and better efficiency in a limited space is an important issue facing antenna design.

Therefore, there is a room for improvement.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of an antenna module of an embodiment of the present disclosure.

FIG. **2** is a schematic diagram of the antenna module shown in FIG. **1** from another angle.

FIGS. **3**A to **3**J are schematic diagrams of a radiation portion in the antenna module according to the embodiment of the present disclosure.

FIG. **4** is a schematic diagram of the antenna module arranged on one side of a radiation body according to an embodiment of the present disclosure.

FIG. **5** is a schematic diagram of the antenna module and the radiation body shown in FIG. **4** at another angle.

FIG. **6** is a schematic diagram of the antenna module applied to an electronic device of an embodiment of the present disclosure.

FIG. **7** is a schematic diagram of the circuit connection of the active circuit of the antenna module shown in FIG. **6**.

FIG. **8** is a schematic diagram of the current path of the antenna module shown in FIG. **6**.

FIGS. **9**A to **9**J are graphs of S parameters (scattering parameters) when two or three radiation branches are disposed in the radiation portion of the antenna module according to the embodiment of the present disclosure.

FIGS. **10**A to **10**J are efficiency graphs when two or three radiation branches are disposed in the radiation portion of the antenna module according to the embodiment of the present disclosure.

DETAILED DESCRIPTION

In order to make the purpose, technical solutions and advantages of the embodiments of the present disclosure clearer, the technical solutions in the embodiments of the present disclosure will be described clearly and completely in conjunction with the drawings in the embodiments of the present disclosure. Based on the embodiments of the present disclosure, all other embodiments obtained by those of ordinary skill in the art without creative work shall fall within the scope of protection of the present disclosure.

Those skilled in the art should understand that, in the disclosure of the present disclosure, "at least one" refers to one or more, and multiple refers to two or more. Unless

otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by those skilled in the technical field in the present disclosure. The terminology used in the specification of present disclosure is only for the purpose of describing specific embodiments, and is not intended to limit the present disclosure.

It can be understood that, unless otherwise specified in the present disclosure, "/" means "or". For example, AB can mean A or B. "A and/or B" in the present disclosure is only an association relationship describing the associated objects, which means that there can be three relationships: only A, only B, and A and B.

It can be understood that, in the disclosure of the present disclosure, the words such as "first" and "second" are only used for the purpose of distinguishing description, and cannot be understood as indicating or implying relative importance, nor as indicating or implying order. The features defined with "first" and "second" may explicitly or implicitly include one or more of the features. In the description of the embodiments of the present disclosure, the words such as "exemplary" or "for example" are used as examples, illustrations, or illustrations. Any embodiment or design solution described as "exemplary" or "for example" in the embodiments of the present disclosure should not be construed as being more preferable or advantageous than other embodiments or design solutions. To be precise, the words such as "exemplary" or "for example" are used to present related concepts in a specific manner.

Those skilled in the art should understand that, in the disclosure of the present disclosure, the terms "longitudinal", "lateral", "upper", "lower", "front", "rear", "left", "right", the orientation or positional relationship indicated by "vertical", "horizontal", "top", "bottom", "inner", "outer", etc. are based on the orientation or positional relationship shown in the drawings, which is only for the convenience of describing the present disclosure and to simplify the description, rather than indicating or implying that the device or element referred to must have a specific orientation, or be constructed and operated in a specific orientation, so the above terms should not be understood as limiting the present disclosure.

FIGS. **1** and **2** illustrate an antenna module **100** in accordance with an embodiment of the present disclosure. The antenna module **100** includes a substrate **11**, a radiation portion Patch, an active circuit **13** (shown in FIG. **2**), and a connector **14** (shown in FIG. **2**).

The substrate **11** may be a dielectric substrate, for example, a printed circuit board (PCB), a ceramic (ceramics) substrate or other dielectric substrate, which is not specifically limited herein. The base substrate **11** includes a first surface **111** and a second surface **112**, and the second surface **112** is disposed opposite to the first surface **111**.

In the embodiment of the present disclosure, the radiation portion Patch is in the shape of a metal flake as a whole. The radiation portion Patch is disposed on the first surface **111** of the substrate **11**. The radiation portion Patch may be connected to the second surface **112** of the substrate **11** through a through hole (via).

Please also refer to FIG. **3**A, in one of the embodiments, the radiation portion Patch is generally rectangular, and its surface is not provided with any gaps, slots, breakpoints, etc. Two or more (for example, two as shown in the figure) signal feed points **121** are provided on one side of the radiation portion Patch. The signal feed point **121** is used to electrically connect to a corresponding feeding source (not shown in the figure, see detailed later) through a matching circuit (not shown in the figure, see detailed later), and then feed electrical signals to the radiation portion Patch. In addition, the antenna module **100** covers different frequency bands by switching the radiation portion Patch to different signal feed point **121**.

The embodiment of the present disclosure does not limit the specific shape and structure of the radiation portion Patch. For example, please also refer to FIG. **3**B, in another embodiment of the present disclosure, the radiation portion Patch is generally rectangular. The radiation portion Patch defines a slot **122**, and the slot **122** is used to divide the radiation portion Patch into a plurality of radiation branches. For example, in the embodiment shown in FIG. **3**B, the slot **122** is substantially L-shaped. After extending a distance from one long side of the radiation portion Patch to another long side, the slot **122** is bent at a right angle to extend in a direction parallel to the long side, and close to the short side of the connector **14**, until it extends and separates the short side. Thus, the slot **122** separates one of the long sides and the short sides of the radiation portion Patch, thereby forming an L shape as a whole, and dividing the radiation portion Patch into a first radiation branch Patch**1** and a second radiation branch Patch**2** that are arranged at intervals. In the embodiment of the present disclosure, one radiation branch (for example, the first radiation branch Patch**1**) is L-shaped, and the other radiation branch (for example, the second radiation branch Patch**2**) is rectangular. The two radiation branches are respectively provided with corresponding signal feed point **121**, and then the corresponding radiation branches are fed with electrical signals respectively.

Please also refer to FIG. **3**C, in another embodiment of the present disclosure, the radiation portion Patch has a rectangular shape as a whole. The radiation portion Patch defines a slot **122**, and the slot **122** is used to divide the radiation portion Patch into a plurality of radiation branches. For example, in the embodiment shown in FIG. **3**C, the slot **122** is substantially L-shaped. After extending a distance from one long side of the radiation portion Patch to the other long side, the slot **122** is bent at a right angle to extend in a direction parallel to the long side and close to the short side of the connector **14**, until it extends to the short side. Therefore, the slot **122** separates one of the long sides and the short sides of the radiation portion Patch, thereby forming an L shape as a whole, and dividing the radiation portion Patch into a first radiation branch Patch**1** and a second radiation branch Patch**2** that are arranged at intervals. In the embodiment of this present disclosure, one of the radiation branches (for example, the first radiation branch Patch**1**) is L-shaped, and the other radiation branch (for example, the second radiation branch Patch**2**) is rectangular. The two radiation branches are respectively provided with corresponding signal feed point **121**, and then the corresponding radiation branches are fed with electrical signals respectively. In the embodiment shown in FIG. **3**C, it is different from the embodiment shown in FIG. **3**B in that the arrangement of the slot **122** is different, as a result, the shapes of the first radiation branch Patch**1** and the second radiation branch Patch**2** are slightly different from those of the first radiation branch Patch**1** and the second radiation branch Patch**2** in FIG. **3**B.

Please also refer to FIG. **3**D, in another embodiment of the present disclosure, the radiation portion Patch has a rectangular shape as a whole. The radiation portion Patch defines a slot **122**, and the slot **122** is used to divide the radiation portion Patch into a plurality of radiation branches. In the embodiment shown in FIG. **3**D, the arrangement of the slot **122** is substantially the same as the arrangement of the slot **122** shown in FIG. **3**C, the difference is that the size and ratio of the first radiation branch Patch**1** and the second radiation branch Patch**2** are slightly different. For example, the area of the first radiation branch Patch**1** shown in FIG. **3**D is larger than that of the first radiation branch Patch**1** shown in FIG. **3**C. Correspondingly, the area of the second radiation branch Patch**2** shown in FIG. **3**D is smaller than that of the second radiation branch Patch**2** shown in FIG. **3**C. In the embodiment shown in FIG. **3**D, the ratio of the first radiation branch Patch**1** and the first radiation branch Patch**1** is different from the ratio of the first radiation branch Patch**1** and the second radiation branch Patch**2** shown in FIG. **3**C, and is slightly larger than the ratio of the first radiation branch Patch**1** to the second radiation branch Patch**2** shown in FIG. **3**C.

Please also refer to FIG. **3**E, in another embodiment of the present disclosure, the radiation portion Patch has a rectangular shape as a whole. The radiation portion Patch defines a slot **122**, and the slot **122** is used to divide the radiation portion Patch into a plurality of radiation branches. In the embodiment shown in FIG. **3**E, the arrangement of the slot **122** is substantially the same as the arrangement of the slot **122** shown in FIG. **3**C, the difference is that the size and ratio of the first radiation branch Patch**1** and the second radiation branch Patch**2** are slightly different. For example, the area of the first radiation branch Patch**1** shown in FIG. **3**E is larger than that of the first radiation branch Patch**1** shown in FIG. **3**C. Correspondingly, the area of the second radiation branch Patch**2** shown in FIG. **3**E is smaller than that of the second radiation branch Patch**2** shown in FIG. **3**C. In the embodiment shown in FIG. **3**E, the ratio of the first radiation branch Patch**1** and the second radiation branch Patch**2** is different from the ratio of the first radiation branch Patch**1** and the second radiation branch Patch**2** shown in FIG. **3**C.

Please also refer to FIG. **3**F, in another embodiment of the present disclosure, the radiation portion Patch has a rectangular shape as a whole. The radiation portion Patch defines a slot **122**, and the slot **122** is used to divide the radiation portion Patch into a plurality of radiation branches. In the embodiment shown in FIG. **3**F, the slot **122** is strip-shaped as a whole (that is, in a straight shape), and it extends from one of the short sides of the radiation portion Patch in a direction parallel to the long side thereof, until it extends to the other relatively short side of the radiation portion Patch further, to divide the radiation portion Patch into a first radiation branch Patch**1** and a second radiation branch Patch**2** arranged at intervals. The first radiation branch Patch**1** and the second radiation branch Patch**2** are both rectangular, and both are arranged parallel to the long side of the radiation portion Patch. In the embodiment of the present disclosure, each radiation branch is provided with a corresponding signal feed point **121**, and then the corresponding radiation branch is fed with electrical signals.

As shown in FIG. **3**B to FIG. **3**F, the radiation portion Patch is divided into two radiation branches by setting a slot **122**. The area allocation of the two radiation branches can be adjusted proportionally according to the bandwidth requirements, so that a wider frequency coupling effect can be provided through a large area. For example, when the radiation branch of the radiation portion Patch is close to the radiation body (such as a metal frame), the two are not in contact, the signal can be transmitted to the radiation body through coupling, and the radiation body can transmit/receive the signal. When the area distribution of the radiation branch is larger, the signal will be transmitted/received from the radiation body through coupling, and the resulting bandwidth will be wider, thereby realizing a larger area to provide a wider frequency coupling effect.

In other embodiments, the number of the slot **122** is not limited, the radiation portion Patch is not limited to one slot **122**. For example, please also refer to FIG. **3**G in another embodiment of the present disclosure, the radiation portion Patch is approximately rectangular, and the radiation portion Patch is provided with a plurality of (for example, two slots **122**) slots **122**. The shape of the slot **122** is generally L-shaped, and its opening method is similar to the opening method of the slot **122** in the embodiment shown in FIG. **3**B, and the radiation portion Patch is further divided into multiple (for example, three) radiation branches (for example, the first radiation branch Patch**1**, the second radiation branch Patch**2**, and the third radiation branch Patch**3**). The first radiation branch Patch**1**, the second radiation branch Patch**2**, and the third radiation branch Patch**3** are spaced apart from each other. The first radiation branch Patch**1** and the second radiation branch Patch**2** are both L-shaped. The third radiation branch Patch**3** has a rectangular shape. The first radiation branch Patch**1**, the second radiation branch Patch**2** and the third radiation branch Patch**3** are arranged in the lower left corner, the middle, and the upper right corner of the radiation portion Patch in order, and their sizes decrease in order. In the embodiment of the present disclosure, each radiation branch is provided with a corresponding signal feed point **121**, and the corresponding radiation branch is fed with electrical signals.

Please also refer to FIG. **3**H, in another embodiment of the present disclosure, the radiation portion Patch is roughly rectangular, and the radiation portion Patch defines a slot **122**. The slot **122** is an irregular shape, which extends from a long side of the radiation portion Patch (for example, the long side of the bottom side) and bends for many times, and finally extends to a short side that separates the radiation portion Patch (for example, close to the short side of the connector **14**), and the radiation portion Patch is divided into a plurality of (for example, two) radiation branches (for example, the first radiation branch Patch**1** and the second radiation branch Patch**2**). The first radiation branch Patch**1** and the second radiation branch Patch**2** are spaced apart from each other. The first radiation branch Patch**1** is roughly S-shaped. The second radiation branch Patch**2** is substantially in the shape of a non-closed mouth, and is arranged on the periphery of the first radiation branch Patch**1**. In the embodiment of the present disclosure, each radiation branch is provided with a corresponding signal feed point **121**, and the corresponding radiation branch is fed with electrical signals.

Please also refer to FIG. **3**I, in another embodiment, the radiation portion Patch is substantially rectangular, the radiation portion Patch defines a plurality of slots **122**, for example, two slots **122**, one of the slot **122** is L-shaped, and the other slot **122** is zigzag-shaped. One ends of the two slot **122** are both set on a long side (for example, the long side of the bottom side) of the radiation portion Patch, and are spaced apart from each other, then start to extend separately, and then all extend to a short side of the radiation portion Patch (for example, the short side close to the connector **14**), and the short side is also spaced apart, and the radiation portion Patch is divided into a plurality of (for example, three) radiation branches (for example, the first radiation branch Patch**1**, the second radiation branch Patch**2** and the third radiation branch Patch**3**). The first radiation branch Patch**1**, the second radiation branch Patch**2** and the third radiation branch Patch**3** are spaced apart from each other. The first radiation branch Patch**1** is roughly C-shaped and is arranged on one side of the radiation portion Patch. The second radiation branch Patch**2** is substantially in the shape of an inverted T, which is arranged between the first radiation branch Patch**1** and the third radiation branch Patch**3**, and the third radiation branch Patch**3** is rectangular. In the embodiment shown in FIG. **3**I, the area of the third radiation branch Patch**3** is the smallest, and each radiation branch is provided with a corresponding signal feed point **121**, which in turn feeds electrical signals to the corresponding radiation branches.

Please also refer to FIG. **3**J, in another embodiment, the radiation portion Patch is roughly rectangular, the radiation portion Patch defines a plurality of slots **122**, for example, two slots **122**. One of the slot **122** is L-shaped, and the other slot **122** is zigzag-shaped. One ends of the two slot **122** are respectively arranged on the two long sides of the radiation portion Patch, and are spaced apart from each other, then start to extend separately, and then all extend to a short side that separates the radiation portion Patch (for example, the short side close to the connector **14**), and the short side is also spaced apart, to divide the radiation portion Patch into the plurality of radiation branches, for example, three radiation branches (such as the first radiation branch Patch**1**, the second radiation branch Patch**2** and the third radiation branch Patch**3**). The first radiation branch Patch**1**, the second radiation branch Patch**2** and the third radiation branch Patch**3** are spaced apart from each other. The first radiation branch Patch**1** is approximately L-shaped, and is disposed at the bottom of the radiation portion Patch. The second radiation branch Patch**2** is approximately π-shaped, and is arranged between the first radiation branch Patch**1** and the third radiation branch Patch**3**. The third radiation branch Patch**3** has a rectangular shape. In the embodiment shown in FIG. **3**J, the area of the third radiation branch Patch**3** is the smallest, and each radiation branch is provided with a corresponding signal feed point **121**, which in turn feeds electrical signals to the corresponding radiation branches.

As shown in FIGS. **3**A to **3**J, for a single radiation portion Patch, the radiation branches divided by the radiation portion Patch can be rectangular, L-shaped, non-closed mouth-shaped, S-shaped, C-shaped, T-shaped, π-shaped or a combination thereof, to work together to excite the corresponding frequency band.

In other embodiments, the shape and structure of the radiation portion Patch are not limited to those described above, and may also be other shapes and structures, which are not specifically limited herein.

In the embodiment of the present disclosure, as shown in FIGS. **3**B to **3**F, the two ends of the slot **122** can be arranged on two adjacent sides of the radiation portion Patch (for example, the long side and the short side described above) or on the two opposite sides, and by changing the shape and arrangement position of the slot **122**, the radiation branches of different shapes can be cut out.

Please refer to FIG. **2**, in the embodiment of the present disclosure, the active circuit **13** is disposed on the second surface **112** of the substrate **11**. The second surface **112** of the substrate **11** is provided with connection lines (not shown). The connection line is connected to the active circuit **13**. The active circuit **13** may include a switch, and/or other adjustable elements that can change impedance (not shown in the figure, see details below). The active circuit **13** can be electrically connected to the radiation portion Patch and the connector **14** through the connection line. For example, in one of the embodiments, the substrate **11** is further provided with a via hole (not shown), and the radiation portion Patch can be connected to the second surface **112** of the substrate **11** through the via hole, and connected to the active circuit **13** through the connection line on the second surface **112**.

The connector **14** is arranged on the second surface **112** of the substrate **11**, the connector **14** is arranged on the surface where the active circuit **13** is located. In some embodiments, the connector **14** and the active circuit **13** may be spaced apart and electrically connected to each other. In the embodiment of the present disclosure, the specific positional relationship and connection relationship between the connector **14** and the active circuit **13** are not limited. For example, in one of the embodiments, the active circuit **13** can be disposed in the connector **14**, the connector **14** can be used to accommodate the active circuit **13**. The connector **14** is electrically connected to the active circuit **13** and connected to a corresponding transmission line, and then realizes the signal transmission of the antenna module **100** through the transmission line, for example, realizes signal sending or sending.

It can be understood that the transmission line can be, but is not limited to, a coaxial cable (coaxial cable), a flexible printed circuit board (flexible printed circuit board, FPCB) or other transmission lines.

Please refer to FIG. **4** and FIG. **5** together, when the antenna module **100** is used, the antenna module **100** can be arranged on one side of a radiation body **200**. The antenna module **100** is provided with a radiation portion Patch on one side facing the radiation body **200**. Therefore, signals can be transmitted and/or received by the radiation body **200** through the coupling of the radiation portion Patch and the radiation body **200**. In addition, the antenna module **100** can also use the switch of the active circuit **13** to switch multi-modes, thereby realizing multiple broadband operations.

For example, in one of the embodiments, when the radiation portion Patch of the antenna module **100** includes three radiation branches, and the active circuit **13** is provided, the three radiation branches are arranged at intervals, and are arranged at intervals from the radiation body **200**, to receive 4G/5G intermediate frequency signals (frequency range of 1.7 GHz-2.2 GHz), high frequency signals (frequency range of 2.3 GHz-2.7 GHz), ultra high band (UHB) signals (frequency range of 3.3 GHz-5 GHz), GPS signal (frequency range of 1.5 GHz-1.6 GHz), Wi-Fi signal (frequency range of 2.4 GHz, 5 GHz).

In the embodiment of the present disclosure, the frequency of the antenna module **100** is not limited. For example, the shape, length, width and other parameters of the antenna module **100** can be adjusted to adjust the required frequency. The shape, length, width and other parameters of the radiation portion Patch can also be adjusted according to the required frequency.

In the embodiment of the present disclosure, the radiation body **200** can be any conductor, such as iron, copper foil on a PCB soft board, a conductor in a laser direct structuring (LDS) process, etc., which are not specifically limited here. For example, in one of the embodiments, the radiation body **200** is a metal frame of an electronic device. The radiation body **200** is disposed on a back plate **305** and is spaced apart from an electronic component, such as a battery **303**. The antenna module **100** is arranged between the radiation body **200** and the battery **303**. The battery **303** is arranged on a middle frame **307**, the middle frame **307** is disposed on the back plate **305** (see details below).

In the embodiment of the present disclosure, the radiation portion Patch and the radiation body **200** are spaced apart. For example, the radiation portion Patch and the radiation body **200** are arranged in parallel. For another example, the radiation portion Patch and the radiation body **200** are spaced apart, but not parallel to each other. In other embodiments, the radiation portion Patch may also be directly connected or not connected to the radiation body **200**. For example, in one of the embodiments, the radiation portion Patch is spaced apart from the radiation body **200**, and is connected to the radiation body **200** through a connection wire. For another example, in another embodiment, the radiation portion Patch and the radiation body **200** are spaced apart, and there is no electrical connection between the radiation portion Patch and the radiation body **200**.

In the embodiments of the present disclosure, the specific structure of the radiation body **200**, and/or its connection relationship with other components are not limited. For example, the side end of the radiation body **200** may be connected to the ground (the radiation body **200** is grounded), or not connected to the ground. For another example, the radiation body **200** may be provided with breakpoints or no breakpoints, broken slots.

Please refer to FIG. **6**, in an embodiment of the present disclosure, the antenna module **100** can be applied to an electronic device **300** to transmit and receive radio waves to transmit and exchange wireless signals. The electronic device **300** may be a handheld communication device (such as a mobile phone), a folding machine, a smart wearable device (such as a watch, earphone, etc.), a tablet computer, a personal digital assistant (personal digital assistant, PDA), which is not specifically limited here.

The electronic device **300** may adopt one or more of the following communication technologies: Bluetooth (BT) communication technology, global positioning system (GPS) communication technology, wireless fidelity (Wi-Fi) communication technology, global system for mobile communications (GSM) communication technology, wideband code division multiple access (WCDMA) communication technology, long term evolution (LTE) communication technology, 5G communication technology, SUB-6G communication technology and other future communication technologies.

In the embodiment of the present disclosure, the electronic device **300** is a mobile phone as an example for description.

Please refer to FIG. **6**, in one embodiment, the electronic device **300** includes a battery **303**, a frame **304**, a back plate **305**, a ground plane **306**, and a middle frame **307** (shown in FIG. **5**). The frame **304** is made of metal or other conductive materials. The back plate **305** may be made of metal or other conductive materials. The frame **304** is disposed on the edge of the back plate **305** and forms an accommodating space **308** together with the back plate **305**. An opening (not shown in the figure) is provided on the side of the frame **304** opposite to the back plate **305** for accommodating a display unit (not shown).

The display unit has a display plane, and the display plane is exposed at the opening. It can be understood that the display unit can be combined with a touch sensor to form a touch screen. The touch sensor can also be called touch panel or touch sensitive panel.

In the embodiment of the present disclosure, the display unit has a high screen-to-body ratio. That is, the area of the display plane of the display unit is greater than 70% of the front area of the electronic device, and even a front full screen can be achieved. Specifically, in the embodiment of the present disclosure, the full screen means except for the necessary slots opened on the electronic device **300**, the left, right, and lower sides of the display unit can be seamlessly connected to the frame **304**.

The ground plane **306** may be made of metal or other conductive materials. The ground plane **306** can be disposed in the accommodating space **308** enclosed by the frame **304** and the back plate **305**, and is connected to the back plate **305**.

The middle frame **307** is made of metal or other conductive materials. The shape and size of the middle frame **307** can be smaller than the ground plane **306**. The middle frame **307** is stacked on the ground plane **306**. In this embodiment, the middle frame **307** is a metal sheet disposed between the display unit and the ground plane **306**. The middle frame **307** is used to support the display unit, provide electromagnetic shielding, and improve the mechanical strength of the electronic device **300**.

In the embodiment, the frame **304**, the back plate **305**, the ground plane **306**, and the middle frame **307** may form an integrally formed metal frame. The backplane **305**, the ground plane **306**, and the middle frame **307** are made of large-area metal, so they can jointly form the system ground plane of the electronic device **300** (not shown in the figure).

The battery **303** is arranged on the middle frame **307** to provide electrical energy for the electronic components, modules, circuits of the electronic device **300**. The battery **303** and the frame **304** are spaced apart, and a slit **309** is formed between the battery **303** and the frame **304**.

In other embodiment, the electronic device **300** may also include one or more of the following components, such as a processor, a circuit board, a memory, an input and output circuit, an audio component (such as a microphone and a speaker), and a multimedia component (such as a front camera and/or a rear camera), sensor components (such as proximity sensors, distance sensors, ambient light sensors, acceleration sensors, gyroscopes, magnetic sensors, pressure sensors and/or temperature sensors), which will not be repeated here.

When the antenna module **100** is applied to the electronic device **300**, the antenna module **100** can be arranged in the slit **309** and arranged substantially perpendicular to the plane where the ground plane **306** is located. A part of the frame **304** constitutes the radiation body **200**, and a gap **310** is defined on the frame **304**. The gap **310** partitions the frame **304** to divide the frame **304** into a first part **311** and a second part **312** which are arranged at intervals. The first part **311** constitutes the radiation body **200**. The second part **312** may be electrically connected to the system ground plane, such as the ground plane **306**.

The gap **310** may be connected to the slit **309** and be filled with insulating materials, such as plastic, rubber, glass, wood, ceramics, but not limited to this. In one embodiment, a ground point **313** is provided on the side of the first part **311** (the radiation body **200**) away from the gap **310**. One end of the ground point **313** is electrically connected to the first part **311**, and the other end is electrically connected to the middle frame **307**, that is, grounded. The antenna module **100** is disposed in the slit **309** between the gap **310** and the ground point **313**, and is disposed substantially perpendicular to the plane where the ground plane **306** is located.

When the antenna module **100** is disposed in the slit **309**, the radiation portion Patch on the antenna module **100** faces the first part **311**, and spaced apart from the first part **311**. The connector **14** is arranged on the other surface of the substrate **11**, that is, it is arranged away from the first part **311**. One end of the connector **14** is electrically connected to the middle frame **307**, and the other end is electrically connected to the substrate **11**.

The radiation portion Patch in the antenna module **100** is divided into three radiation branches by the slot **122**, such as the first radiation branch Patch**1**, the second radiation branch Patch**2**, and the third radiation branch Patch**3** as an example. Please refer to FIG. **6** and FIG. **7**, each radiation branch includes a corresponding signal feed point (for example, signal feed points port**1**, port**2**, and port**3**, the aforementioned signal feed point **121**). Each signal feed point is electrically connected to the corresponding feed source through the corresponding matching unit. For example, the signal feed point port**1** of the first radiation branch Patch**1** is electrically connected to the feeding source **161** through the matching unit **151**. The signal feed point port**2** of the second radiation branch Patch**2** is electrically connected to the feeding source **162** through the matching unit **152**. The signal feed point port**3** of the third radiation branch Patch**3** is electrically connected to the feeding source **163** through the matching unit **153**.

The active circuit **13** in the antenna module **100** is disposed in the connector **14**. As shown in FIG. **7**, the active circuit **13** includes a switch **131** and adjustable elements **132**, **133**, **134**. One end of the switch **131** is electrically connected to the connector **14**, and the other end of the switch **131** is electrically connected to a corresponding feed source through corresponding adjustable elements **132**, **133**, **134**. For example, the switch **131** is electrically connected to the feeding source **161** through the adjustable element **132**, the switch **131** is electrically connected to the feeding source **162** through the adjustable element **133**, and the switch **131** is electrically connected to the feeding source **163** through the adjustable element **134**. That is, the matching circuit includes at least a matching unit **151**, a matching unit **152**, and a matching unit **153**.

The antenna module **100** can divide the radiation portion Patch into the plurality of radiation branches, and the plurality of radiation branches are coupled to the first part **311** to resonate to form an adjustable mode. The coupling state between two adjacent radiation branches can be controlled, and independent modes with tunability and good antenna efficiency can be generated through coupling. The switching of the switch **131** in the active circuit **13** can switch multiple modes, and use multiple adjustable elements (for example, adjustable elements **132**, **133**, **134**) to achieve multiple frequency bands.

FIG. **8** is a schematic diagram of the current path of the electronic device **300**. The first radiation branch Patch**1** with signal feed point port**1** can excite Wi-Fi 2.4G (such as path P**1**), Wi-Fi 5G (such as path P**2**) and License Assisted Access (LAA) modes. The Wi-Fi 2.4Q Wi-Fi 5G and LAA frequency bands can be coupled and resonated by using the slit **309**, which has the best antenna efficiency, and the working frequency range of the first radiation branch Patch**1** can cover the Wi-Fi 2.4G frequency band (2400 MHz-2484 MHz), Wi-Fi 5G frequency band (5150 MHz-5850 MHz) and LAA frequency band (5150 MHz-5925 MHz).

The second radiation branch Patch**2** with signal feed point port**2** can excite UHB mode and 5G Sub6 NR mode (such as path P**3**). UHB band and 5G Sub6 NR band can be coupled and resonated by using slit **309**, which has the best antenna efficiency. The operating frequency range of the second radiation branch Patch**2** can cover the UHF frequency band (3400 MHz-3800 MHz) and 5G Sub6 NR frequency band (for example, 5G Sub6 N77 frequency band (3300 MHz-4radiation body 200 MHz), 5G Sub6 N78 frequency band (3300 MHz-3800 MHz) And 5G Sub6 N79 frequency band ((4400 MHz-5000 MHz) frequency band).

The third radiation branch Patch**3** with the signal feed point port**3** can excite the medium and high frequency modes (such as path P**4**), mid- and high-frequency bands can be coupled and resonated by using slit **309**, which has the best antenna efficiency. The working frequency range of the third radiation branch Patch**3** can cover the intermediate frequency of GSM1800/1900/WCDMA2100 frequency band (1710 MHz-2170 MHz), and the high frequency LTE B7, B40, B41 frequency band (2300 MHz-2690 MHz).

The switch **131** is a mid-high frequency/UHB and NR/Wi-Fi 2.4Q Wi-Fi 5G and LAA switch, used to switch mid-high frequency/UHB and NR/Wi-Fi 2.4Q Wi-Fi 5G and LAA Frequency band.

The antenna module **100** can be applied to the electronic device **300**, to increase the antenna efficiency bandwidth and have the best antenna efficiency, and the switching of the switch **131** can effectively improve the antenna frequency coverage. In one embodiment, the applicable working frequency range of the antenna module **100** can cover the intermediate frequency of 1710 MHz to 2170 MHz, the high frequency of 2300 MHz-2690 MHz, UHF 3400 MHz to 3800 MHz, Wi-Fi 2.4Q Wi-Fi 5G and LAA, and can support 5G Sub6 N77/N78/N79 frequency bands.

The antenna module **100** can set the radiation portion Patch as an independent sheet body, or use the slot **122** to divide the radiation portion Patch into the plurality of radiation branches, and set corresponding signal feed points at appropriate positions of the radiation portion Patch or the plurality of radiation branches, and the radiation body **200** (or the metal frame of the electronic device **300**, for example, the first part **311**) is used as a metal radiator, the radiation body **200** and the antenna module **100** couple the energy to resonate the mode in the slit **309**, to cover medium, high frequency, UHF, 5G Sub6 N77, 5G Sub6 N78, 5G Sub6 N79, Wi-Fi 2.4Q Wi-Fi 5G frequency bands, so as to greatly increase its bandwidth and antenna efficiency, and can also cover the world's commonly used 5G The application of communication frequency bands and the requirements of Carrier Aggregation (CA) supporting LTE-A (short for LTE-Advanced, which is the subsequent evolution of LTE technology).

FIGS. **9**A to **9**J are graphs of S parameters (scattering parameters) when the antenna module **100** uses the slot **122** to divide the radiation portion Patch into two or three radiation branches. As shown in FIG. **9**A, FIG. **9**C, FIG. **9**D, FIG. **9**E and FIG. **9**F, the first radiation branch Patch**1** covers UHF 3400-3800 MHz, and can support 5G Sub N77/N78/N79 frequency bands. The second radiation branch Patch**2** covers intermediate frequency 1710-2170 MHz and high frequency 2300-2690 MHz. As shown in FIG. **9**B, the first radiation branch Patch**1** covers the intermediate frequency of 1710-2170 MHz and the high frequency of 2300-2690 MHz, the second radiation branch Patch**2** covers UHF 3400-3800 MHz, and can support 5G Sub N77/N78/N79 frequency bands. As shown in FIG. **9**Q the first radiation branch Patch**1** covers the intermediate frequency of 1710-2170 MHz and the high frequency of 2300-2690 MHz, the second radiation branch Patch**2** covers GPS, Wi-Fi 2.4Q Wi-Fi 5G and LAA frequency bands. As shown in FIG. **9**H, FIG. **9**I and FIG. **9**J, the first radiation branch Patch**1** covers the intermediate frequency of 1710-2170 MHz and the high frequency of 2300-2690 MHz, the second radiation branch Patch**2** covers UHF 3400-3800 MHz, and can support 5G Sub N77/N78/N79 frequency bands. The third radiation branch Patch**3** covers Wi-Fi 2.4G, Wi-Fi 5G and LAA frequency bands.

The switch **131** switches to different signal feed points, the frequency mode can be controlled to cover the intermediate frequency of 1710-2170 MHz, the high frequency of 2300-2690 MHz, UHF 3400-3800 MHz, GPS, Wi-Fi 2.4Q Wi-Fi 5G and LAA frequency bands, and can support 5G Sub N77/N78/N79 frequency bands.

FIGS. **10**A to **10**J are efficiency graphs when the antenna module **100** uses the slot **122** to divide the radiation portion Patch into two or three radiation branches. FIG. **10**A shows the radiation efficiency (Rad. shown in the figure) and total efficiency (Tot. shown in the figure) values of each radiation branch when the radiation portion Patch in the antenna module **100** is divided into two radiation branches as shown in FIG. **3**B (namely, the first radiation branch Patch**1** and the second radiation branch Patch**2**). As shown in FIG. **10**A, FIG. **10**C, FIG. **10**D, FIG. **10**E and FIG. **10**F, the first radiation branch Patch**1** covers UHF 3400-3800 MHz, and can support 5G Sub N77/N78/N79 frequency bands. The second radiation branch Patch**2** covers the intermediate frequency of 1710-2170 MHz and the high frequency of 2300-2690 MHz. As shown in FIG. **10**B, the first radiation branch Patch**1** covers the intermediate frequency of 1710-2170 MHz and the high frequency of 2300-2690 MHz, the second radiation branch Patch**2** covers UHF 3400-3800 MHz, and can support 5G Sub N77/N78/N79 frequency bands. As shown in FIG. **10**G the first radiation branch Patch**1** covers the intermediate frequency of 1710-2170 MHz and the high frequency of 2300-2690 MHz, the second radiation branch Patch**2** covers GPS, Wi-Fi 2.4G; Wi-Fi 5G and LAA frequency bands. As shown in FIG. **10**H, FIG. **10**I and FIG. **10**J, the first radiation branch Patch**1** covers the intermediate frequency of 1710-2170 MHz and the high frequency of 2300-2690 MHz, the second radiation branch Patch**2** covers UHF 3400-3800 MHz, and can support 5G Sub N77/N78/N79 frequency bands. The third radiation branch Patch**3** covers Wi-Fi 2.4G Wi-Fi 5G and LAA frequency bands.

The antenna module **100** sets the switch **131** and makes the switch **131** switch to different signal feed points, to control the frequency mode, and cover the intermediate frequency (1710 MHz-2170 MHz), the high frequency (2300 MHz-2690 MHz), UHF (3400 MHz-3800 MHz), Wi-Fi 2.4G Wi-Fi 5G and LAA, and can support 5G Sub6 N77/N78/N79 frequency bands.

Even though numerous characteristics and advantages of the present technology have been set forth in the foregoing description, together with details of the structure and function of the present disclosure, the disclosure is illustrative only, and changes may be made in the detail, especially in matters of shape, size, and arrangement of the parts within the principles of the present disclosure, up to and including the full extent established by the broad general meaning of the terms used in the claims. It will therefore be appreciated that the exemplary embodiments described above may be modified within the scope of the claims.

What is claimed is:

1. An antenna module comprising:

a substrate;

a radiation portion disposed on the substrate; wherein the radiation portion is a complete sheet body made of conductive material, at least one signal feed point is disposed on one side of the radiation portion to feed electrical signals to the radiation portion respectively; wherein the radiation portion defines at least one slot, and the slot divides the radiation portion into radiation branches disposed at intervals, and each radiation branch is electrically connected to a corresponding signal feed point to feed electrical signals to each radiation branch; and an active circuit disposed on the substrate; wherein the active circuit is electrically connected to the radiation portion to switch radiation modes of the radiation portion.

2. The antenna module according to claim **1**, wherein area allocation of the radiation branches is adjusted in proportion to a bandwidth requirement, to provide a wide band coupling effect through a large area.

3. The antenna module according to claim **1**, wherein the substrate comprises a first surface and a second surface, the first surface is disposed facing the radiation portion, the second surface is disposed opposite to the first surface, the radiation portion is disposed on the first surface, and the active circuit and a connector are disposed on the second surface.

4. The antenna module according to claim **1**, wherein two ends of the slot are arranged on two adjacent sides or two opposite sides of the radiation portion, and the radiation branches of different shapes are cut out by changing a shape and a arrangement position of the slot.

5. The antenna module according to claim **1**, wherein the active circuit comprises a switch and a plurality of adjustable elements, a frequency radiation mode of the antenna module is controlled by switching the switch to a corresponding adjustable element and a corresponding feed source, to cover an intermediate frequency band, a high frequency band, a ultra-high frequency band (UHB), a global positioning system (GPS) radiation mode, a Wi-Fi 2.4G frequency band, a Wi-Fi 5G frequency band, a licensed spectrum assisted access (LAA) frequency band, and a 5G Sub6 NR frequency band.

6. The antenna module according to claim **1**, wherein the antenna module further comprises a radiation body, the radiation body and the radiation portion are spaced apart, the radiation body and the radiation portion are coupled to each other to generate a plurality of radiation modes, and transmit and/or receive signals through the radiation body.

7. An electronic device comprising:

an antenna module comprising:

a substrate;

a radiation portion disposed on the substrate; wherein the radiation portion is a complete sheet body made of conductive material, at least one signal feed point is disposed on one side of the radiation portion to and feed electrical signals to the radiation portion respectively; wherein the radiation portion defines at least one slot, and the slot divides the radiation portion into radiation branches disposed at intervals, and each radiation branch is electrically connected to a corresponding signal feed point, to feed electrical signals to each radiation branch;

an active circuit disposed on the substrate; wherein the active circuit is electrically connected to the radiation portion to switch radiation modes of the radiation portion.

8. The electronic device according to claim **7**, wherein area allocation of the radiation branches is adjusted in proportion to a bandwidth requirement, to provide a wide band coupling effect through a large area.

9. The electronic device according to claim **7**, wherein the substrate comprises a first surface and a second surface, the first surface is disposed facing the radiation portion, the second surface is disposed opposite to the first surface, the radiation portion is disposed on the first surface, and the active circuit and a connector are disposed on the second surface.

10. The electronic device according to claim **7**, wherein two ends of the slot are arranged on two adjacent sides or two opposite sides of the radiation portion, and the radiation branches of different shapes are cut out by changing a shape and a arrangement position of the slot.

11. The electronic device according to claim **7**, wherein the active circuit comprises a switch and a plurality of adjustable elements, a frequency radiation mode of the antenna module is controlled by switching the switch to a corresponding adjustable element and a corresponding feed source, to cover an intermediate frequency band, a high frequency band, a ultra-high frequency band (UHB), a global positioning system (GPS) radiation mode, a Wi-Fi 2.4G frequency band, a Wi-Fi 5G frequency band, a licensed spectrum assisted access (LAA) frequency band, and a 5G Sub6 NR frequency band.

12. The electronic device according to claim **7**, wherein the antenna module further comprises a radiation body, the radiation body and the radiation portion are spaced apart, the radiation body and the radiation portion are coupled to each other to generate a plurality of radiation modes, and transmit and/or receive signals through the radiation body.

13. The electronic device according to claim **7**, wherein the electronic device further comprises a metal frame, part of the metal frame constitutes a radiation body, the radiation body and the radiation portion are spaced apart, and the radiation body and the radiation portion are coupled to each other to generate plurality of radiation modes, and transmit and/or receive signals through the radiation body.

14. The electronic device according to claim **13**, wherein the metal frame defines a gap, the gap separates the metal frame to divide the metal frame into a first part and a second part arranged at intervals, the first part constitutes the radiation body, and the second part is grounded.

15. The electronic device according to claim **14**, wherein a ground point is disposed on one side of the first part away from the second part, a first terminal of the ground point is electrically connected to the first part, and a second terminal of the ground point is grounded.

16. The electronic device according to claim **15**, wherein the electronic device further comprises a battery, the battery and the metal frame are spaced apart, and a slit is formed between the battery and the metal frame, and the antenna module is disposed in the slit between the gap and the ground point, and the radiation portion and the first part are spaced apart.

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